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MCDONNELL DOUGLAS
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APPLICATION OF SHUTTLE EVA SYSTEMS TO PAYLOADS

FINAL REPORT
CONTRACT NAS 9-14678

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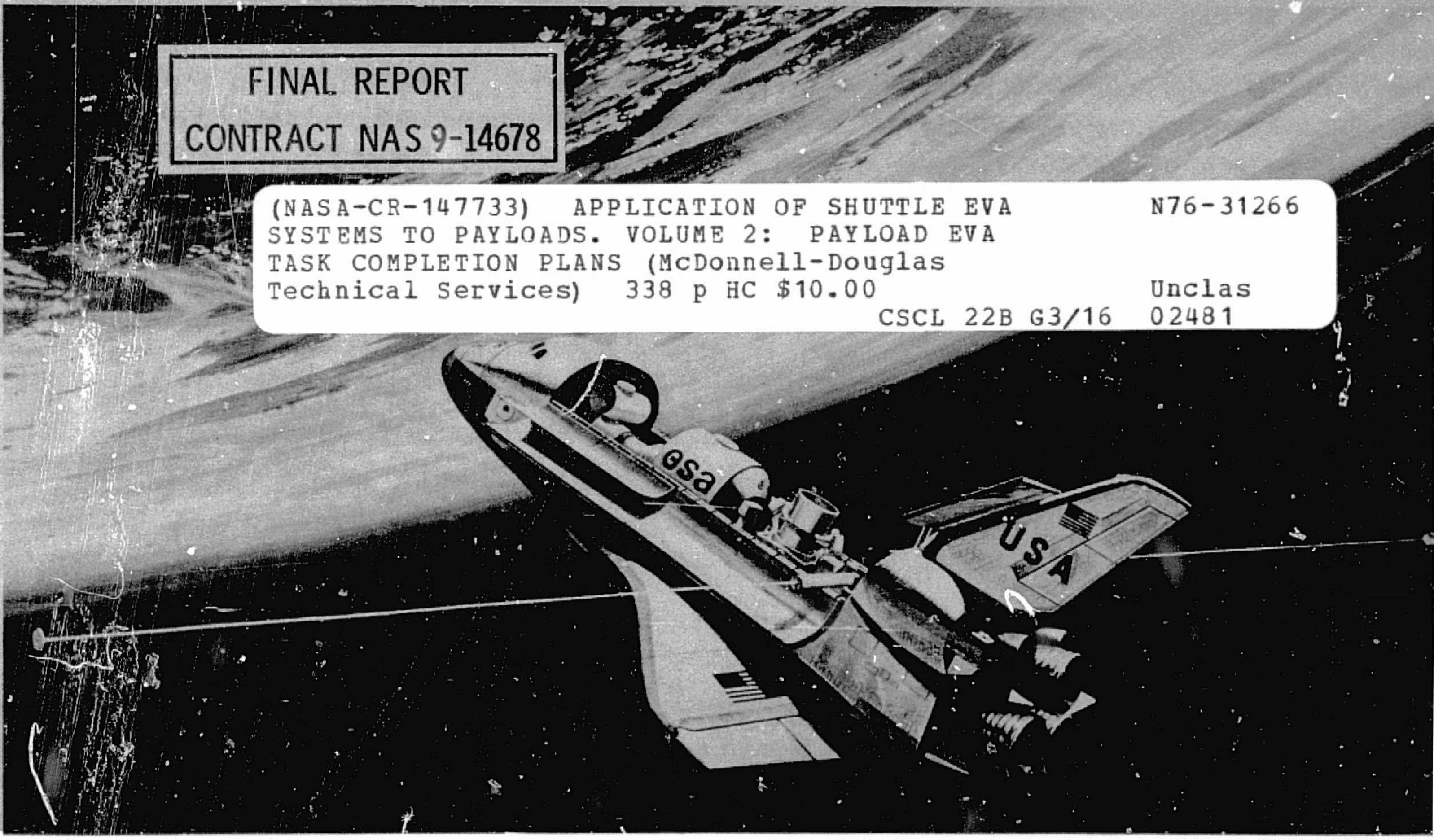

VOLUME II:

PAYLOAD EVA TASK COMPLETION PLANS

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FINAL REPORT
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VOLUME II:

PAYLOAD EVA TASK COMPLETION PLANS

PREPARED FOR:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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SPACE SHUTTLE EVA

FOREWORD

Numerous experiments have been identified for Shuttle applications ranging from space exposure of various material samples to planetary soil return missions including a search for the "edge" of the universe. Payload systems to support the numerous experiment operations are being developed with emphasis on providing the greatest scientific return per dollar invested in equipment and transportation. Servicing, repairing, and refurbishing payloads are some of the more significant economic measures that can be applied either through ground based or orbital operations.

Since manned extravehicular activity (EVA) is a qualified, prime candidate for economically conducting on-orbit payload support functions, this study was designed to assist in correlating experiment and payload requirements with EVA capabilities, systems and operational modes. The study was sponsored by the Bioengineering Division, Life Sciences Office of NASA Headquarters, Dr. Stanley Deutsch, Director. The work was monitored under the technical direction of Mr. John H. Covington, Crew Training and Procedures Division, Flight Operations Directorate of the Lyndon B. Johnson Space Center (JSC), Houston, Texas. The Contracting Officer was Mr. Thomas R. McPhillips, Program Procurement Division, JSC.

Major objectives of the study were as follows: (1) to develop a comprehensive description of the Space Shuttle baseline EVA systems including candidate EVA-assisted operational modes; (2) identify and select candidate payload tasks across representative payloads for EVA application; and (3) develop payload EVA task completion plans including preliminary EVA operational procedures and timelines. The study was performed over a twelve-month period beginning June 1975.

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The final report for the contract is presented in two volumes:

Volume I: EVA Systems and Operational Modes Description

Volume II: Payload EVA Task Completion Plans

This document (Volume II) identifies and selects candidate payload tasks for EVA application based on an analysis of four representative Shuttle payloads and develops typical EVA scenarios with supporting crew timelines and procedures. The volume also summarizes the EVA preparation and post EVA operations and timelines emphasizing concurrent payload support functions.

ACKNOWLEDGEMENTS

The NASA Technical Monitor for the study was Mr. John H. Covington, Crew Training and Procedures Division, Flight Operations Directorate, Johnson Space Center, Houston, Texas. Contract monitoring and technical assistance were provided by Mr. David C. Schultz, Chief, Crew Systems Branch, and Mr. Raymond G. Zedekar, Chief, EVA Systems Section of the Crew Training and Procedures Division. Special appreciation is expressed to Dr. Stanley Deutsch, Director, Bioengineering Division, Office of Life Sciences, NASA Headquarters, for his efforts in arranging for the conduct of the study.

Significant contributions in obtaining quantitative data and technical information were provided by personnel within the NASA Johnson Space Center. Sincere appreciation is due Mr. Jack C. Heberlig/LP, Mr. Ted H. Skopinski/LP, Mr. Stewart L. Davis/LO, Mr. Robert L. Frost/LP, Mrs. Jeri W. Brown/EW5, Mr. Jerry R. Goodman/EK3, Dr. Karl G. Henize/TE, and Mr. Gary D. Meester/LP.

The contractor Principal Investigator for the study was Mr. Nelson E. Brown, Study Manager, McDonnell Douglas Technical Services Company, Houston Astronautics Division, McDonnell Douglas Corporation. Principal contributors within McDonnell Douglas were Mr. John F. Schuessler and Mr. William L. Yeakey.

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ACRONYMS AND ABBREVIATIONS

ACS	Attitude Control System
ARC	Ames Research Center
ASMU	Automatically Stabilized Maneuvering Unit
ASTRO	Astrometry Instrument
ATL	Advanced Technology Laboratory
BTU/hr	British Thermal Units per hour
CCA	Communications Carrier Assembly
CCC	Contamination Control Cartridge
CCTV	Closed Circuit Television
C. G.	Center of Gravity
Cm, cm	Centimeter
CMG	Control Moment Gyro
CO_2	Carbon Dioxide
CRT	Cathode Ray Tube
CSD	Crew Systems Division
C&W	Caution and Warning
DCM	Displays and Controls Module
DMS	Data Management Subsystem
dia	Diameter
ECLSS	Environmental Control/Life Support System
ECS	Environmental Control System
EEE	Environmental Effects Experiment
EEH	EMU Electrical Harness
EMU	Extravehicular Mobility Unit
EPS	Electrical Power System
EOS	Earth Observatory Satellite
EST	Eastern Standard Time
EV	Extravehicular
EVA	Extravehicular Activity
EVC	Extravehicular Communication

ACRONYMS AND ABBREVIATIONS (Continued)

EVCS	Extravehicular Communication System
EVVA	Extravehicular Visor Assembly
FOS	Faint Object Spectrograph
FSS	Flight Support Station
ft	Foot
gm	Gram
gm-Cal	Gram-Calorie
GN_2	Gaseous Nitrogen
GO_2	Gaseous Oxygen
GSFC	Goddard Space Flight Center
HGA	High Gain Antenna
HHMU	Hand Held Maneuvering Unit
HRC	High Resolution Camera
HRS	High Resolution Spectrograph
HSAP	High Speed Area Photometer
HUT	Hard Upper Torso
I&CS	Instrumentation and Communications Subsystem
IDB	Insuit Drink Bag
in	Inch
IPS	Instrument Pointing System
IPS	Integrated Payload System
IR	Infrared
IRP	Infrared Photometer
IRTCM	Integrated Real-Time Contamination Monitor
IVA	Intravehicular Activity
JSC	Johnson Space Center
kg	Kilogram
kg/cm^2	Kilogram per square centimeter
KSC	Kennedy Space Center
lb	Pound

ACRONYMS AND ABBREVIATIONS (Continued)

lbf	Pound force
LaRC	Langley Research Center
LCG	Liquid Cooling Garment
LCMS	Low Cost Modular Spacecraft
LGA	Low Gain Antenna
LSS	Life Support System
LST	Large Space Telescope
M, m	Meter
Max	Maximum
MDTSCO	McDonnell Douglas Technical Services Company, Inc.
MEM	Modular Exchange Mechanism
MLI	Multi-Layered Insulation
MM	Module Magazine
mm	Millimeter
mmHg	Millimeters Mercury
MMS	Multimission Modular Spacecraft
MMU	Manned Maneuvering Unit
MOC	Mission Operations Center
MS	Mission Station
MSFC	Marshall Space Flight Center
MSS	Module Support Structure
N	Newtons
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
N-m	Newton-Meter
N-mi	Nautical Mile
O_2	Oxygen
OMS	Orbital Maneuvering System
OTA/SI	Optical Telescope Assembly/Scientific Instruments
OWS	Orbital Workshop

ACRONYMS AND ABBREVIATIONS (Continued)

PAM	Propulsion/Actuation Module
PAM	Pulse Amplitude Modulation
PCS	Pointing Control System
PIDA	Payload Installation Deployment Aids
P/L	Payload
PLSS	Portable Life Support System
POS	Portable Oxygen System
PP	Positioning Platform
PRPS	Payload Retention and Positioning System
PRS	Personnel Rescue System
PS	Payload Station
psia	Pounds per square inch absolute
PSS	Payload Specialist's Station
RC	Retention Cradle
RMS.	Remote Manipulator System
S&MS	Structure and Mechanical Subsystem
SCU	Service and Cooling Umbilical
SHe	Supercritical Helium
SI	Scientific Instruments
SIRTF	Shuttle Infrared Telescope Facility
SLR	Side-Looking Radar
SOP	Secondary Oxygen Pack
SOW	Statement of Work
SPMS	Special Purpose Manipulator System
SSA	Space Suit Assembly
SSE	Space Support Equipment
SSM	Support Systems Module
SSPD	Space Shuttle Payloads Description
ST	Space Telescope
STDN	Spacecraft Tracking and Data Network

SPACE SHUTTLE EVA

ACRONYMS AND ABBREVIATIONS (Continued)

STS	Space Transportation System
TBD	To Be Determined
TCS	Thermal Control Subsystem
TDRSS	Tracking and Data Relay Satellite System
TPS	Thermal Protection System
TV	Television
UCD	Urine Collection Device
UV	Ultraviolet
WIF	Water Immersion Facility
^{o}C	Degrees Centigrade
^{o}F	Degrees Farenheit
ΔV	Delta Velocity

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SECTION 1.0 INTRODUCTION

A major objective of this Shuttle Extravehicular Activity (EVA) study was to present information to the Shuttle payload community on the capabilities of the Orbiter EVA baseline system. Conversely, the study was also designed to provide the Shuttle EVA system designers an overview of specific payload task requirements. Designers of the EVA systems are not fully cognizant of experiment and payload requirements with potential extravehicular (EV) applications which may be economically advantageous in payload design and operation. Payload designers may not be aware of the availability of Orbiter subsystems and subsystem combinations that can be used to accomplish extravehicular tasks. This report is intended to promote the exchange of information between the payload experimenters and EVA system designers.

1.1 BACKGROUND

The economic constraints on manned space flight are more pronounced on the Space Shuttle Program than in previous U. S. space activities. Both the Space Shuttle launch system and the payloads are pursuing the most economical means of payload transportation and experiment development and operation as is feasible without impacting experiment objectives or flight safety. Payload servicing and refurbishment studies have indicated that extravehicular on-orbit servicing is a prime candidate for economically satisfying payload operational requirements. Much of the EVA support equipment will be provided onboard the primary spacecraft, the Shuttle Orbiter, for safety and contingency situations. Eight Spacelab (Sortie) payloads and six Automated payloads are specifying planned EVA for on-orbit servicing in the early payload design phase. In addition, 97 Spacelab payloads of the 157 identified in the Marshall Space Flight Center Summarized NASA Payload Descriptions documents (Sortie Payloads--July 1975) specify EVA for contingency operations. The Automated payloads specify contingency EVA for 60 of the 84 payloads identified in August 1975.

The Shuttle EVA system is expected to play a major role in payload servicing and refurbishment on both currently defined and future payload missions. The EVA role is further enhanced since the Shuttle system will provide subsystems and equipment to perform three 2-man EVA operations of 6 hours duration on each 7-day Shuttle flight. One EVA capability, however, will always be reserved for contingency rescue operations. Orbiter-provided EV support equipment includes space suits, life support equipment, airlock, equipment servicing provisions, prebreathe subsystems, and all expendables and consumables at no cost to the payload. EVA capability in addition to the Orbiter provisions can be added as mission kits but are chargeable to the payloads.

1.2 SCOPE AND APPROACH

The study effort comprised a combination of data identification, compilation, and analyses of EVA and payload systems followed by selection of potential EVA payload tasks, timeline and procedures development, conceptual designs, and presentation methodologies/formatting. The study consisted of five (5) major tasks and several related subtasks to reach the study milestones. The major tasks are listed below:

- Develop Shuttle EVA systems descriptions
- Identify and develop Shuttle EVA operational modes descriptions
- Identify and select representative EVA payload missions/tasks
- Develop payload EVA task completion plans (timelines and procedures)
- Define payload EVA task support requirements not currently included in the Orbiter baseline system.

The overall study approach is illustrated in Figure 1.1-1. The study results presented in this volume of the final report include Tasks 3 through 5 of the overall study. The results of Tasks 1 and 2 are provided in Volume I.

Task 1 provides a summary description of the Space Shuttle baseline EVA

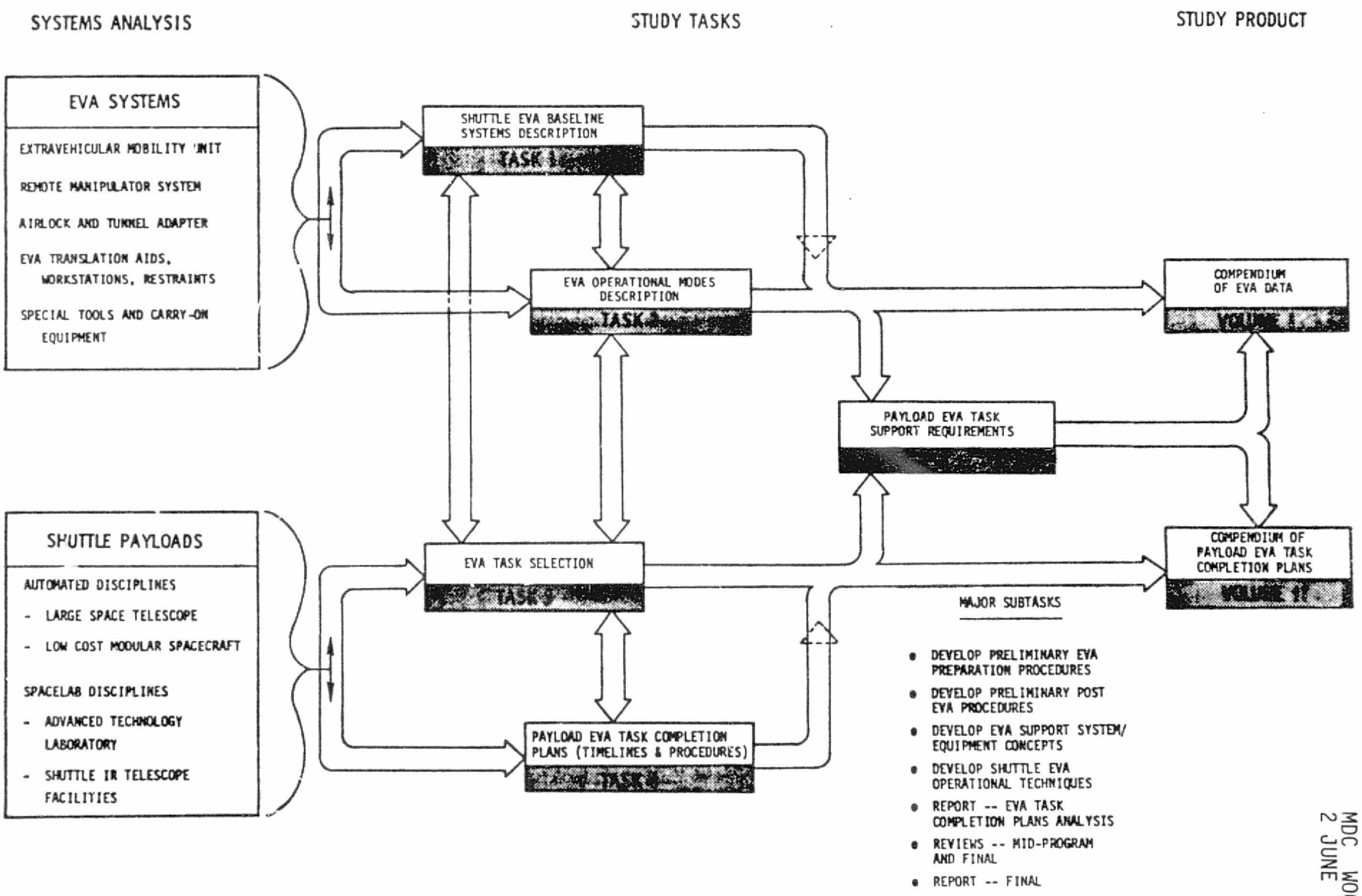

FIGURE 1.1-1: Study Approach and Task Interrelationship

system(s) required to perform planned and candidate on-orbit payload servicing operations. The description provides the physical and operational characteristics of the baseline EVA system including illustrations and drawings. Task 2 identifies and provides a descriptive overview of the available EVA operational modes provided by the Shuttle Orbiter and available to support on-orbit payload servicing functions. The primary operational modes consist of: unaided EVA, EVA with the Remote Manipulator System (RMS), EVA on RMS and EVA with a Manned Maneuvering Unit (MMU). The EVA operational modes description includes performance characteristics and limitations of each system. The study results of the above tasks are provided in Volume I of the final report.

Task 3 presents the results of specific payload analyses and selects potential EVA tasks to conduct typical EV missions. Payload analyses emphasis was placed on the payloads currently designing for planned EVA or studying concepts for EVA servicing, and payloads with potential cost savings through EVA utilization. Task 4 develops EVA procedures and timelines for conducting the typical EVA missions identified in Task 3. The EVA procedures entail crewmen operations from airlock egress through mission operations and terminate following airlock ingress. Task 4 identifies elements of the EVA mission including number of crewmen, translation aids and locations, workstation provisions, lighting, etc.

Task 5 identifies additional EVA support requirements (e.g., subsystems, tools, equipment) necessary to complete the representative payload EVA missions (EVA scenarios) developed as part of Tasks 3 and 4. The additional EVA support equipment requirements are not currently part of the Shuttle baseline EVA system (or payload systems) and are recommended primarily to enhance overall EVA operational capability. Payload task requirements that are beyond the capability of the baseline EVA system were also identified and support equipment defined to permit completion of specific EVA missions.

SECTION 2.0 EVA TASK SELECTION AND TASK COMPLETION PLANS

2.1 INTRODUCTION

The identification, description and selection of representative payload tasks for potential EVA application were derived from an analysis of four candidate payloads scheduled for Shuttle flights in the 1980's. The payloads, selected by the NASA, include the following:

- Advanced Technology Laboratory (ATL)
- Low Cost Modular Spacecraft (LCMS)--Formerly Earth Observatory Satellite (EOS)
- Large Space Telescope (LST)
- Shuttle IR Telescope Facility (SIRTF)

The Shuttle payloads selected contain experiment disciplines from both the Automated and Spacelab payload classifications. The payload selection was designed to allow detail analysis of a minimum number of payloads possessing representative operations and configurations across the total payload community. The payloads were sufficiently diverse to identify and select a number of typical EVA tasks which would inclusively require all baseline EVA systems while utilizing a wide range of EVA crew capabilities.

In the selection of tasks for EVA application, primary emphasis was placed on the analysis of payloads currently either planning for or studying concepts for orbital EVA servicing. Additional EVA operational categories defined for and addressed by this study are unscheduled EVA, contingency EVA and potential planned EVA. The study does not attempt to prioritize the EVA operational categories relative to mission success, equipment salvage, or spacecraft/crew safety. The four EVA operational categories as defined by this study are described in the subsequent section.

2.1.1 EVA Operational Categories

For purposes of this study, EVA is classified into four basic categories defined as follows:

- Planned EVA - Required as the prime method of accomplishing the mission objectives (support of selected payload operations). These tasks are planned and trained for as part of the mission preparation.
- Unscheduled EVA - Tasks which are not planned but which may be required to achieve payload operation success or enhance overall mission success.
- Contingency EVA - All inspection, remedial or rescue activities required to effect safe return of the crew.
- Potential Planned EVA - Activities that could be accomplished by EVA but would require an alteration in mission plans or a change in payload, Orbiter, or EVA hardware. Benefits could include:
  - Reduction in payload subsystem complexity
  - Reduction in Orbiter support systems complexity
  - Reduction in mission cost
  - Efficient utilization of baseline EVA equipment.

Tasks identified for each of the four selected payloads are grouped into one of the above referenced categories.

2.1.2 EVA Task Classification

An assessment of the orbital and transearth EVA operations conducted on past space programs, Shuttle payload plans, and analysis of projected operations has yielded numerous functions that can be effectively performed by man outside the space vehicle. These functions may be combined to provide a general classification of twelve major EVA task functions as listed below:

- Deploy/Retract
- Remove/Replace

- Cargo Transfer
- Assembly/Mating
- Maintain
- Operate/Monitor
- Inspect/Diagnose
- Repair/Refurbish
- Data Acquisition
- Satellite Deploy/Recover
- Crewman Translation
- Astronaut Rescue

The specific requirements associated with each extravehicular function depend upon the particular mission/payload. A general description of major EVA functions was determined and is defined in Table 2.1.1. The task classifications shown in the table are used in describing payload operations for each EVA task identified.

2.1.3 EVA Task Selection

The EVA tasks identified from an analysis of the selected Shuttle payloads are presented in the following subsections. Initially an overall description of each payload, its function, major components, and EV crew interfaces are described based on payload data available in early 1976. Payload operations considered within the capability of present EVA equipment development technology and demonstrated EV crewman capability are listed. The EVA tasks involved in each of the payload operations are described using the EVA task classification provided in Table 2.1.1. Finally, general rationale relative to task performance is presented.

2.1.4 Payload EVA Task Completion Plans

The payload EVA task completion plans encompass the development of preliminary crew procedures and timelines (based on the payload defined tasks), identification of crewman-to-payload interfaces, and development of preliminary Shuttle EVA preparation and post operations and timelines. In order to maintain payload EVA operations continuity from task identification through procedures development, the EVA task completion plans (Task 4) and the EVA task selection (Task 3) products are integrated for presentation in this report.

TABLE 2.1.1: Classification of Typical EVA Tasks

TASK	TASK DEFINITION
DEPLOY/RETRACT	To DEPLOY is to arrange, extend, place, unfold, position, etc. payload components, systems, subsystems, or experiment apparatus and to secure that equipment into its programmed location and configuration. To RETRACT is the reverse function and includes the releasing of the securing device(s) and the retraction, folding, stowing, etc. of the equipment (e.g., DEPLOY/RETRACT antennas, sensors, booms, solar arrays, experiment samples, etc.).
CARGO TRANSFER	CARGO TRANSFER is the transfer, movement, transportation, etc. of materials from one stable point in free space to another including on/off loading, tethering/restraining, inflight stabilization, mass relocation, untethering/unrestraining, special handling, etc. accomplished either manually or assisted by crewman maneuvering equipment (e.g., CARGO TRANSFER of film packages, retrieval of experiment modules, supplies and expendables).
ASSEMBLE/MATE	To ASSEMBLE/MATE is to join, secure, fit together two or more units, components, subassemblies, etc. into a complete system by the performance of various operations that may include sealing/bonding/welding, making of electrical/fluid/mechanical connections, and the positioning/stabilization prior to and during the installation (e.g., antenna assembly/erection, spacecraft assembly, kick stage mating, meteoroid collection equipment, etc.).
MAINTAIN	To MAINTAIN is to perform scheduled, periodic operations required to sustain system efficiency and may include servicing, cleaning, focusing, vessel resupply, aligning, calibrating, tightening, checking, etc. (e.g., MAINTAIN sensors, cleaning lenses and coatings, resupply of fluids, etc.).

TABLE 2.1.1: Classification of Typical EVA Tasks (continued)

TASK	TASK DEFINITION
DATA ACQUISITION	DATA ACQUISITION is the procurement, attainment, or collection of factual information and measurements by sensor/recording equipment. This function may include the positioning of sensors in proximity of phenomenon of interest, the stabilization of sensors, data recording, deactivation of sensor/recorder, etc. (e.g., data or electromagnetic field intensities and patterns, still and movie photography, plasma wake measurements, etc.).
SATELLITE DEPLOY/ RECOVER	SATELLITE DEPLOY is the performance, or assistance in the performance, of various sequential operations that result in the launching or emplacement of free flying satellite/ subsatellite spacecraft into a desired orbit and may include pre-release inspection and checkout, satellite release, post-release inspection, etc. (e.g., DEPLOY experiment subsatellites, orbital storage vessels, automated spacecraft, etc.). SATELLITE RECOVER is the performance or assistance in the performance of various operations to accomplish the retrieval/acquisition of a free flying satellite/subsatellite spacecraft from orbit (may be unstable and uncooperative) and the stabilization of it in the desired position. This function may include satellite rendezvous, pre-recovery inspection, stabilization/grappling, disabling of stabilization system/despinning, removing appendages/expelling expendables, positioning and securing satellite in receptacle, attachment of support umbilicals, etc. (e.g., RECOVER experiment subsatellite(s), automated spacecraft, etc.).
ASTRONAUT RESCUE	ASTRONAUT RESCUE is the acquisition, extraction and retrieval of a disabled EVA astronaut from a hazardous environment and positioning him in a safe location. This may include rendezvous, stabilization, securing, translation and obstacle avoidance, etc. (e.g., recovering astronaut from disabled Manned Maneuvering Unit, other spacecraft, structural entanglement, etc.).

TABLE 2.1.1: Classification of Typical EVA Tasks (continued)

TASK	TASK DEFINITION
OPERATE/MONITOR	To OPERATE is to conduct a series of tasks in a specific sequence to permit continuing performance of systems for meeting mission objectives and may include activation, sequential control, deactivation, etc. To MONITOR is to watch, observe, check, and review the status/progress of events and operations for the purpose of verification, regulation, or feedback control (e.g., experiment or spacecraft systems activation and performance evaluation).
INSPECT/DIAGNOSE	To DIAGNOSE is to investigate or analyze the cause or nature of a condition or phenomenon (e.g., INSPECT/DIAGNOSE as to possible cause(s) and location of pressure leak in spacecraft shell, radiator degradation, thruster malfunction, etc.).
REMOVE/REPLACE	To REMOVE/REPLACE is to perform various operations to remove, detach, displace a module or subassembly from an assembly/system and to replace it with a substitute or superseding item. This function may include releasing, removing, storing, acquiring, replacing, aligning, installing, securing, etc. where special, complex aids should not be required (e.g., REMOVE/REPLACE thruster modules, experiment modules, film canisters, etc.).
REPAIR/REFURBISH	To REPAIR/REFURBISH is to perform appropriate corrective action to renovate, recondition, etc. a damaged or malfunctioning item and to restore it to a usable, operable state. This may include nonscheduled replacement at component level, cutting, sealing/bonding/welding, etc. This function will normally require the use of special aids (e.g., REPAIR/REFURBISH solar array panels, meteoroid damage, thermal coating replacement, etc.).
CREWMAN TRANSLATION (EVA)	CREWMAN TRANSLATION is the safe scheduled movement, transfer, or transportation of crewmen from point to point in free space or on the exterior of a single or docked vehicle(s). Translation support equipment may include handrails/handholds, tethers, MMU's, etc. (e.g., CREWMAN TRANSLATION between undocked vehicles, on the exterior surface of single or integrated vehicles, or in the immediate proximity of any spacecraft.

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To avoid redundancy in the development of EVA procedures and timelines, each payload EVA task identified in the task selection phase is not included in the EVA task completion plans. The quantity of possible EVA tasks defined for each of the payloads is intended to demonstrate the numerous and diverse Shuttle EVA applications. Several of the key EVA tasks were combined to develop representative EVA mission scenarios for each of the selected payloads. Following task selection for the representative EVA missions, trade-off criteria were developed to determine the best approach to task completion using the EVA operational modes defined in Volume I of this report. Task completion plans were then developed.

2.2 ADVANCED TECHNOLOGY LABORATORY (ATL)

2.2.1 ATL Program Description

2.2.1.1 Introduction

The Advanced Technology Laboratories (ATL's) are dedicated, multi-disciplinary sortie payloads particularly suited to the research requirements of the NASA Langley Research Center. The ATL discussed in this document is currently classified as Shuttle Mission 11 in the NASA Integrated Mission Analysis and Planning Schedule (Ref. 2.2.1). The Shuttle Mission 11 ATL is the fifth Shuttle operational flight and the first ATL to orbit and perform a 7-day, Orbiter-attached Sortie mission. The ATL consists of a pressurized, habitable Spacelab and a 6 meter (≈20 ft.) pallet. This ATL payload consists of thirteen experiments selected from payloads ATL-2, ATL-3, and ATL-5. A crew of 6 (3+3) will be required: A commander, pilot, and mission specialist to operate the Orbiter, and three payload specialists for payload operations. The mission 11 ATL experiments consist of communications and navigation, earth observations, physics and chemistry, microbiology, component and systems tests, and environmental effects disciplines. The orbital altitude is 350 km. (189 N. mi.) at an inclination of 57 degrees. The payload is scheduled for launch on May 1, 1980, at 1345 EST from the Kennedy Space Center (KSC) for a 7-day mission. Approximately 132 hours are required for mission completion.

The primary goal of the Advanced Technology Laboratory payloads is to utilize the space environment (e.g., high altitude and velocity, weightlessness, radiation, and earth orbital perspective) to develop and test a wide variety of advanced technology systems and techniques to permit all NASA centers to extend laboratory programs into space.

2.2.1.2 ATL Experiment Description

The Mission 11 ATL experiments were tentatively selected by the NASA Langley Research Center (LaRC) in June 1975 and currently remain under study. The

thirteen experiments are listed in Table 2.2.1 by number and title assigned by the Marshall Space Flight Center (MSFC) Space Shuttle Payload Documents (SSPD)--Ref. 2.2.3 and 2.2.4.

TABLE 2.2.1: ATL Experiments (Mission 11)

SSPD NUMBER	EXPERIMENTS
XST-001	Microwave Interferometer
XST-004	Autonomous Navigation
XST-006	Search and Rescue Aids
XST-008	Imaging Radar
XST-010	Lidar Measurements
XST-019	UV Meteor Spectroscopy
XST-020	Zero g Colony Growth
XST-021	Microorganisms in Zero g
XST-023	Electrical Characteristics of Cells
XST-024	Properties of Biological Cells
XST-026	Zero g Steam Generator
XST-029	Environmental Effects
XST-044	Contamination

The objective of each ATL experiment is described below:

- Microwave Interferometer Navigation and Tracking Aid, XST-001: used to determine the capability of a satellite interferometer technique at L-band frequency to locate low powered radio sources on earth.
- Autonomous Navigation, XST-004: used to determine the capability of a number of navigation techniques for determining orbital position relative to earth ground track.

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- Search and Rescue Aids, XST-006: used to determine the capability of side-looking radar to detect and locate passive earth-located targets.
- Imaging Radar, XST-008: used to determine the capability of imaging radar to obtain satisfactory radar images from low earth orbit.
- Lidar Measurement of Cirrus Clouds and Lower Stratospheric Aerosols, XST-010: used to measure the spatial distribution of cirrus clouds and low stratosphere aerosols.
- Ultraviolet Meteor Spectroscopy from Near Earth Orbit, XST-019: used to obtain quantitative spectra of meteors in wavelengths below 3100 angstroms (Å).
- Colony Growth in Zero-Gravity, XST-020: used to investigate the pattern of growth of bacteria colonies in near zero gravity.
- Interpersonal Transfer of Microorganisms in Zero Gravity, XST-021: used to investigate the interpersonal transfer of microorganisms between crewmen in weightlessness.
- Electrical Characteristics of Cells, XST-023: used to measure the electrophoritic mobility, surface zeta-potential and surface charge density of selected mammalian cell lines.
- Special Properties of Biological Cells, XST-024: used to determine the physical properties of mammalian cells in zero gravity.
- Zero Gravity Steam Generator, XST-026: used to obtain performance data on the operation of the zero gravity steam generator.
- Environmental Effects on Non-Metallic Materials, XST-029: used to investigate and understand space environment effects on elastomers, coatings and polymers.

In addition to the above experiments, an Integrated Real Time Contamination Monitor (IRTCM), Experiment XST-044, will be used to provide simultaneous measurements of contamination composition, deposition rate, particle size and effect on optical surfaces. The experiment will also provide the means

for evaluating the effectiveness of cleaning techniques on surfaces in which contamination has been carefully monitored.

Numerous ATL compatible experiments are being considered by the NASA for application in the Space Technology discipline. Various experiments and payload bay installation configurations are being studied for optimum ATL flights. A tuneable laser (CO_2) with an IR telescope and detector is also under consideration for the first ATL mission. The tuneable laser provides the capability for remote sensing of the earth atmosphere and Shuttle external environment. The tuneable laser may be flown in lieu of the imaging radar on the initial ATL mission; however, this document addresses only the imaging radar configuration.

2.2.1.3 ATL Payload Configuration

The ATL payload baseline configuration consists of three major elements, Figure 2.2-1:

- A pressurized, habitable module consisting of subsystem support equipment for internal accommodation of experiments
- A 6 meter (≈20 ft.) pallet structure providing external mountings for experiments and sensors
- An Integrated Payload System (IPS) consisting of experiments and experiment support equipment housed either in IPS experiment consoles within the pressurized laboratory or mounted on the pallet.

The pressurized laboratory consists basically of a 4.6 m. (180 in.) diameter cylindrical section, 6.1 m. (240 in.) long with 60° conical sections attached at each end, Figure 2.2-2. The aft conical section is removable for installation of experiments and equipment. Access into the laboratory is through a 1.5 m. (60 in.) diameter hatch. The laboratory consists of a crew station console for control and monitoring onboard systems and experiments, a data management console for recording experimental data, a workbench for general operational support, standard equipment racks for

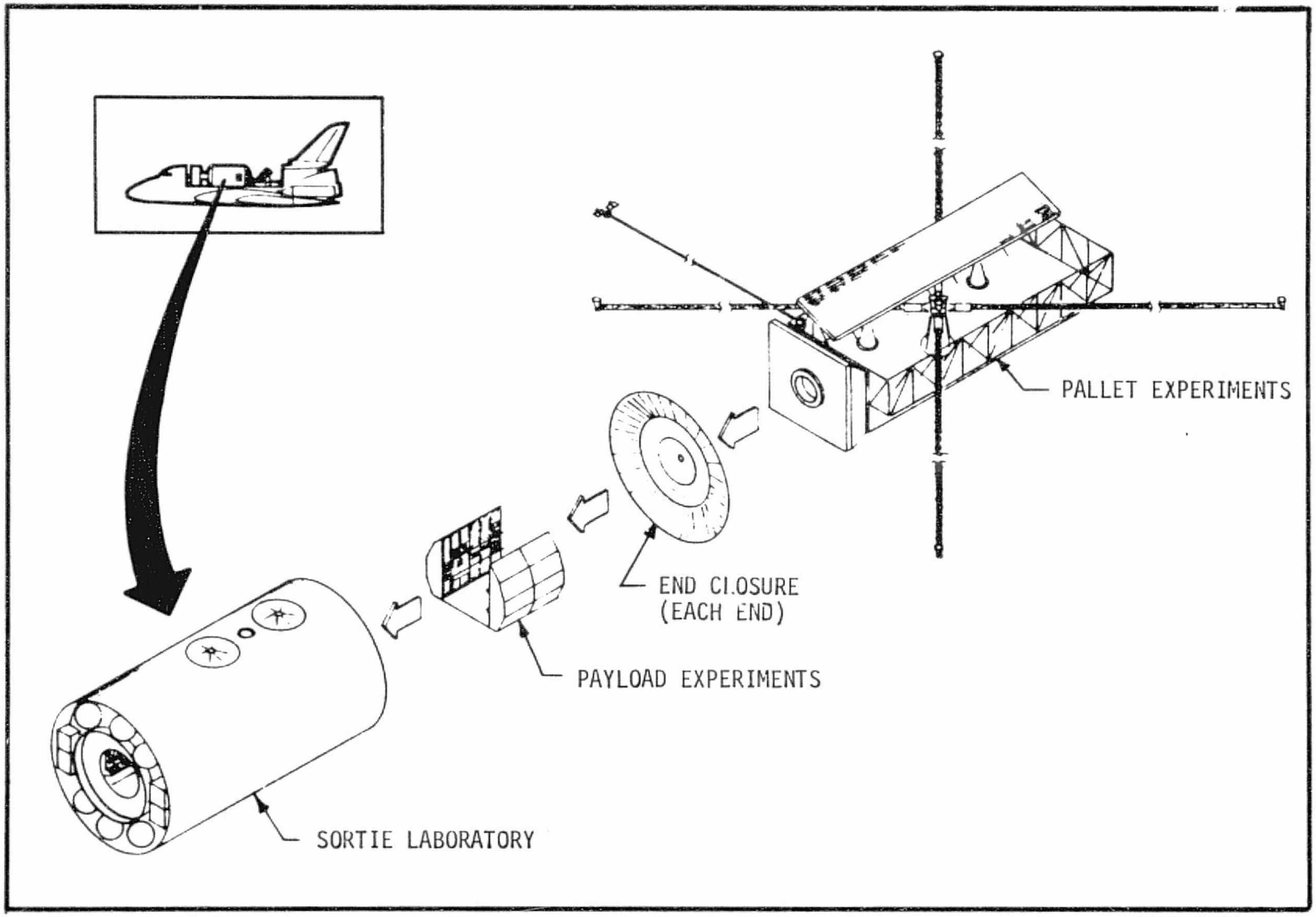

FIGURE 2.2-1: ATL Payload Baseline Configuration
(Shuttle Mission No. 11--Concept)

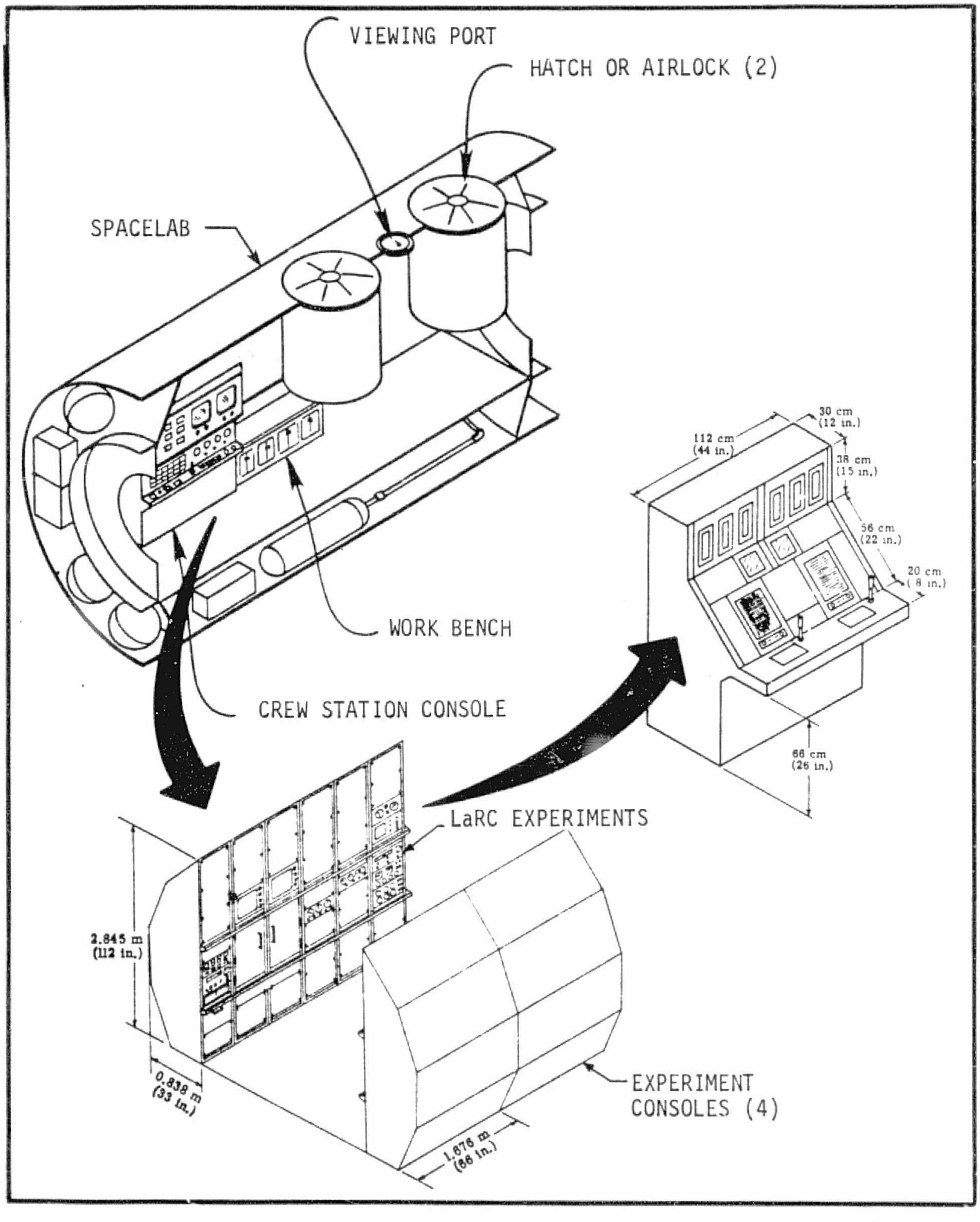

FIGURE 2.2-2: ATL Pressurized Laboratory Configuration (Concept)

housing carry-on electronics, and cabinets for crew personal items. Viewing is accomplished through airlocks and/or observation windows. Two scientific airlocks, located on top of the laboratory, are available for deploying experiments. If an airlock is not used, optical windows or hatches may be installed. The optical windows, approximately one meter (40 in.) in diameter, may be used for experiment observation. Three smaller windows, approximately .3 m. (12 in.) in diameter, are available for experiment viewing: two on the laboratory aft bulkhead and one between the airlocks.

The experiments for ATL with pallet mounted equipment include the following:

- Microwave Interferometer Navigation and Tracking Aid--XST-001
- Autonomous Navigation--XST-004
- Imaging Radar (XST-008) and Search and Rescue Aids--XST-006
- Integrated Real-Time Contamination Monitor--XST-044
- Environmental Effects on Non-Metallic Materials--XST-029.

A preliminary external arrangement of the pallet for the above ATL experiment is depicted in Figure 2.2-3. Descriptions of the major experiment hardware systems (external) are provided in Subsection 2.2.2 of this document.

The Integrated Payload System (IPS) consists of LaRC experiments, experiment support hardware, and structural consoles for housing experiments and equipment. Most experimental supporting electronics and other subsystems are housed within the IPS experiment consoles, Figure 2.2-4. However, certain sensors are located on the unpressurized pallet with supporting electronics located in the consoles. The IPS includes all the equipment and sensors, regardless of location, required for the ATL mission (i.e., Shuttle Mission No. 11). The IPS uses standard consoles which enhances the rapid interchangeability of the ATL interior. Four consoles will support 2.8 m^3 (100 ft^3) of experimental equipment (Ref. Figure 2.2-2).

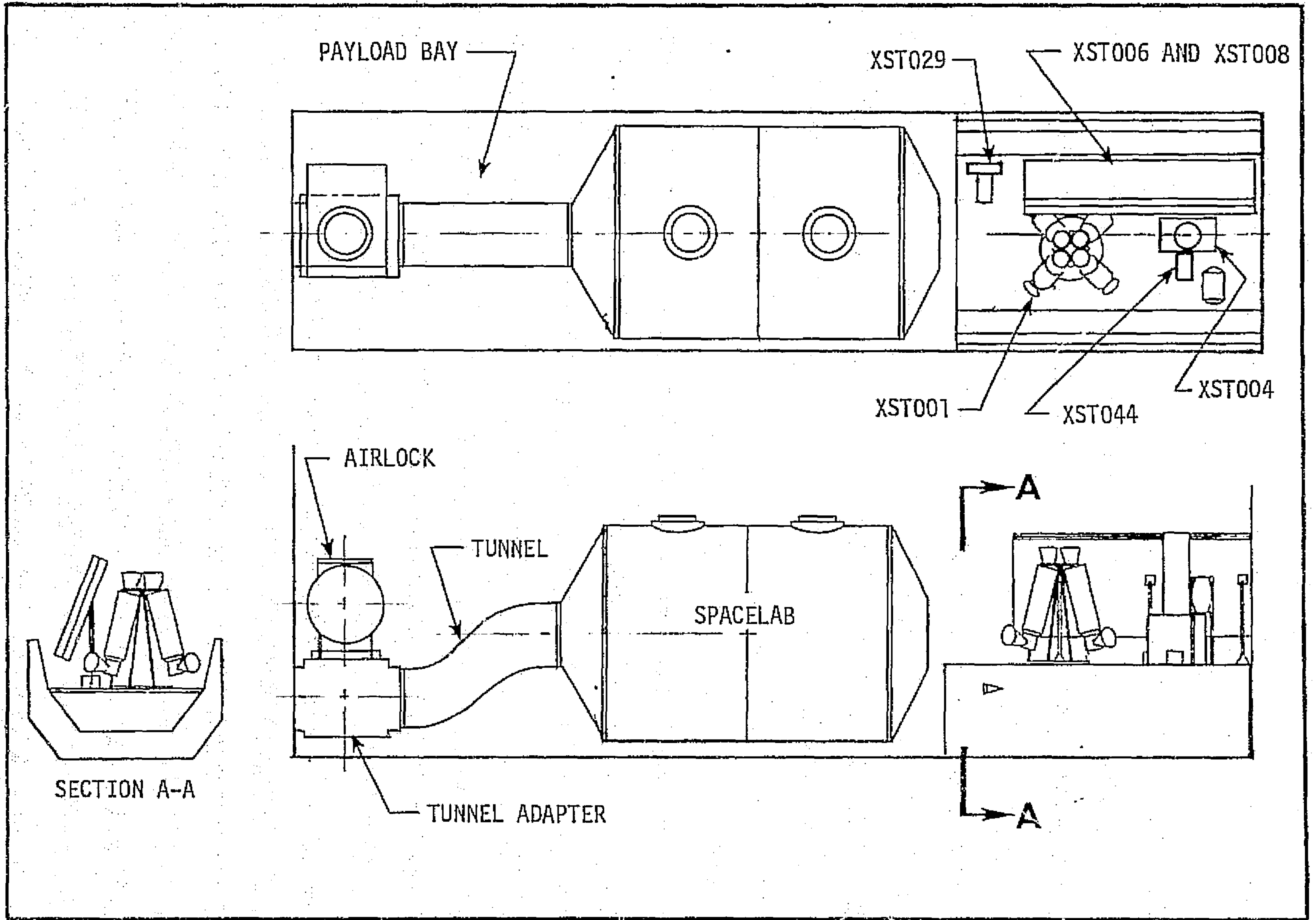

FIGURE 2.2-3: ATL Mission 11 Pallet Experiment Arrangement (Concept)

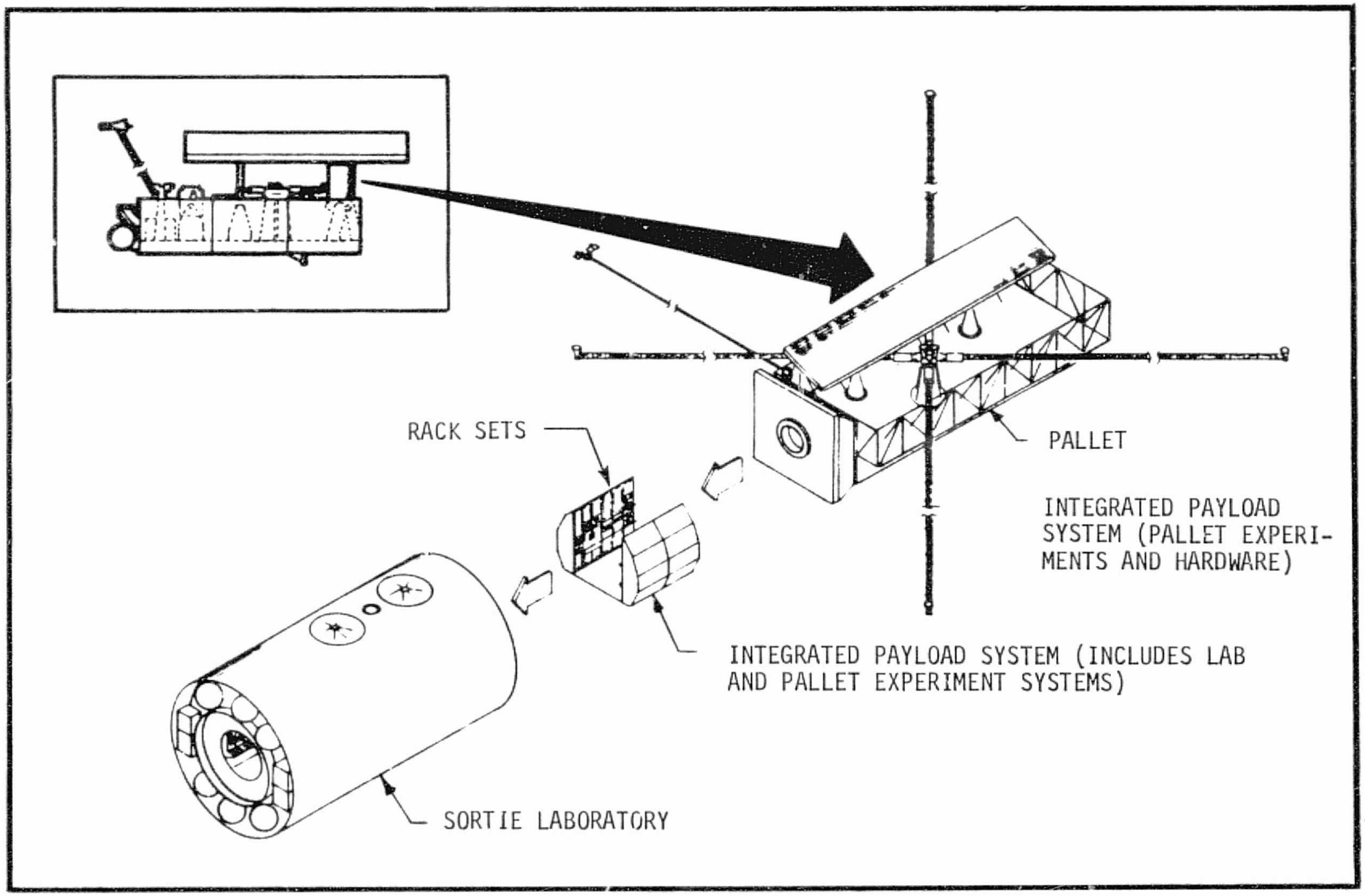

FIGURE 2.2-4: ATL Integrated Payload System (IPS)--Concept

2.2.1.4 ATL EVA Requirements

The ATL pallet mounted equipment is currently being designed (conceptual phase only) for complete operation from within the pressurized laboratory. No planned EVA's are presently being scheduled. Contingency extra-vehicular functions are being considered only in the event of external equipment malfunction or failure. Possible ATL EVA applications identified in later subsections are based on: (1) enhancing mission success; (2) ensuring safe crew and Orbiter return; and (3) hardware modification for economical EVA payload application. The three EVA areas are categorized as unscheduled, contingency, and potential planned EVA (Ref. Section 2.1.1).

2.2.2 ATL Equipment Description--Pallet Mounted

The design of ATL experiment support hardware located outside the pressurized laboratory has been developed only to the conceptual phase. Planning and analyses to select experiments for the initial ATL flights are continuing in early 1976. Pallet mounted equipment for supporting experiment operations (e.g., deployment/retraction mechanisms, jettison devices, backup systems) is not defined to the level required for specifying detailed (candidate) EVA applications. The experiment systems and equipment described below are derived from References 2.2.1 and 2.2.2 and are subject to change as payload development and experiment selection progress.

2.2.2.1 Microwave Interferometer Navigation and Tracking Aid--XST-001

The XST-001 experiment equipment accessible to the EVA crewman consists of a 2.3 kg. (5 lbs.) receiving antenna and preamplifier at each end of extendible, orthogonal booms, boom cannisters, four 38.1 m. (125 ft.) extendible booms, and various boom actuating mechanisms, Figure 2.2-5. Cables from the receiving antennas are deployed along the booms to radio receivers at the hub of the experiment. Extendible booms of the astromast coilable or articulated lattice type are proposed for antenna deployment. The booms are retractable and are stowed for launch and reentry.

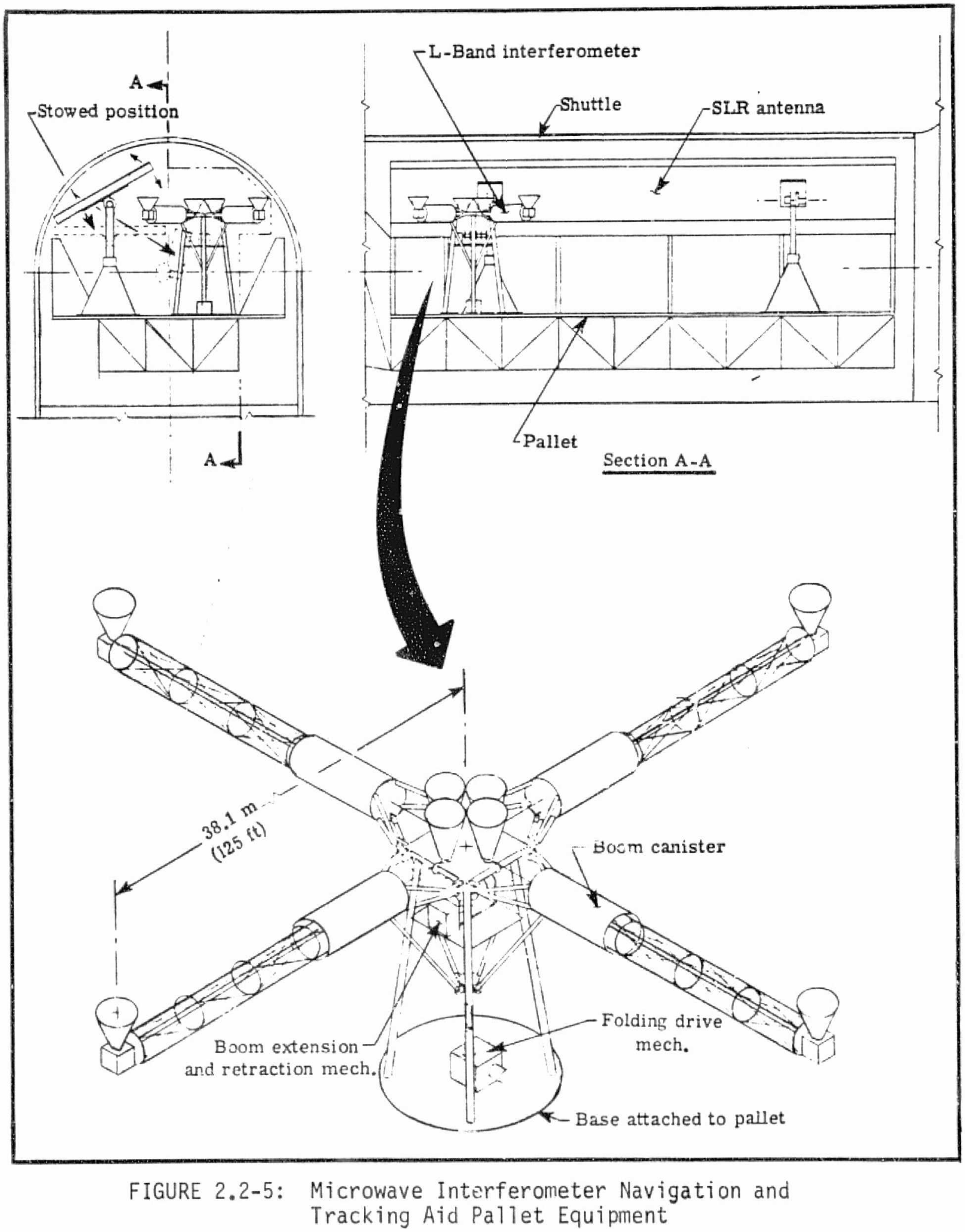

FIGURE 2.2-5: Microwave Interferometer Navigation and Tracking Aid Pallet Equipment

Based on the XST-001 experiment hardware conceptual configurations and mechanical components, EVA can be applied in the unscheduled, contingency, and potential planned EVA categories. Depending on final hardware design and equipment accessibility, unscheduled or contingency EVA can be conducted should equipment malfunctions occur. Design of the XST-001 boom latching and folding mechanisms for manual operation could be cost effective both in initial design and launch weight cost.

2.2.2.2 Autonomous Navigation--XST-004

The autonomous navigation experiment designers are considering a single telescope coupled to a coherent optical parallel image correlator with an inertial reference unit as the major pallet mounted equipment. The equipment is to be mounted within a platform assembly with rotation provided by the Orbiter to gain viewing of both the starfield and the Earth, Figure 2.2-6. The basic design being considered uses a 20 cm. (7.9 in.) clear aperture Schmidt-Cassegrain telescope with an 8^{0} field of view, a one-watt He-Ne laser, a 25 mm. (.98 in.) wafer image intensifier, paraboloidal mirror segments, fixed multiplexed matched spatial filter, image dissector electro-optical readout system, and an optical-to-optical input imaging device.

2.2.2.3 Imaging Radar--XST-008--and Search and Rescue Aids--XST-006

The ATL imaging radar and search and rescue aids experiments use a slotted waveguide array antenna mounted on a pallet to perform the experiments. The antenna, its deployment/retraction mechanisms and the radar units may be candidates for EVA operations.

The imaging radar experiment employs a side-looking radar (SLR), spectrum analyzer, magnetic recorder, photographic camera, analog-to-digital converter, buffer, slotted waveguide array antenna, and supporting electronics, Figure 2.2-7. The tilting antenna is deployed beyond the payload bay doors during orbital operations. Dimensions of the major components are shown in Figure 2.2-7.

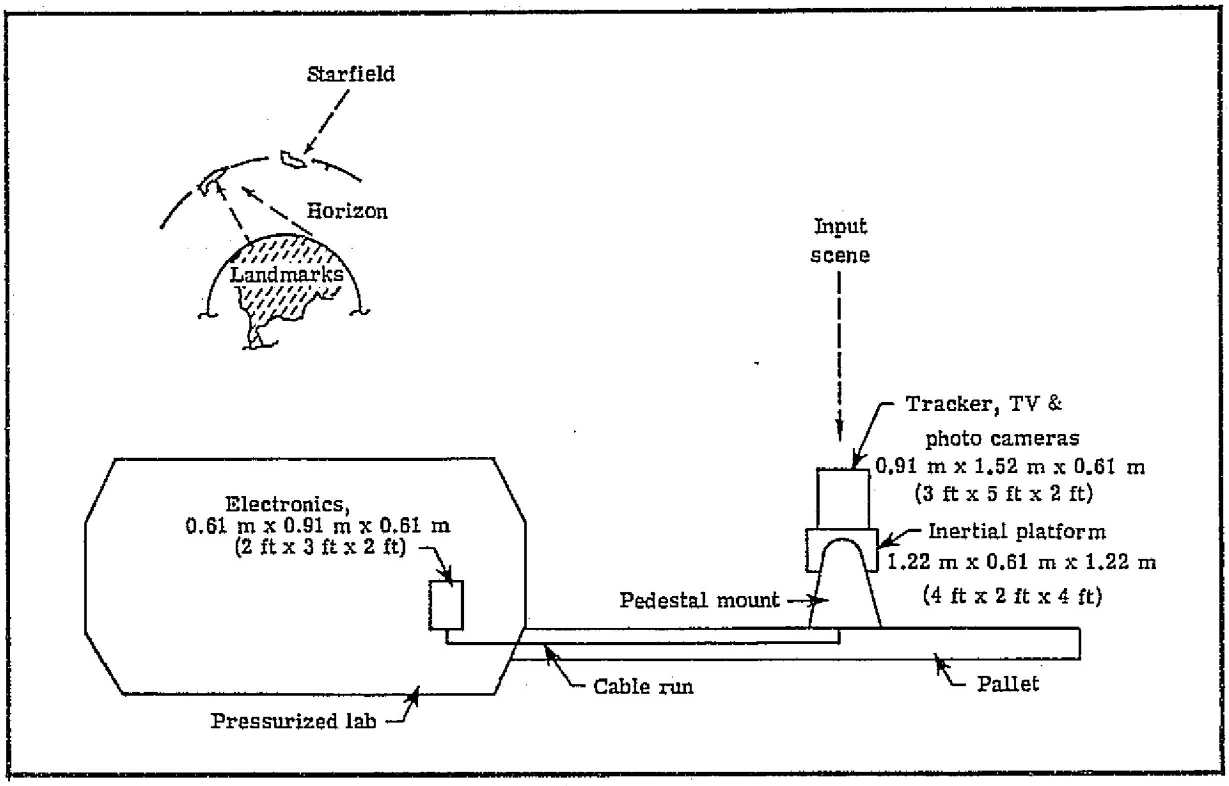

FIGURE 2.2-6: ATL Autonomous Navigation Experiment
--Pallet Equipment

The search and rescue aids experiment uses a side-looking radar (SLR), target reflectors (spheres, corner reflectors, Luneberg lens), slotted waveguide array antenna, and supporting instrumentation located in the pressurized laboratory, Figure 2.2-8. A simplified block diagram of the side-looking radar for the search and rescue aids ATL experiment is shown in Figure 2.2-9.

Detail design of the pallet mounted equipment is not currently available for identifying EVA crewman-to-hardware interfaces or possible ATL EVA applications. As in the previously identified ATL experiments, candidate EVA applications appear to be in the unscheduled and contingency areas to enhance mission success or perform maintenance operations to ensure safe crew return. Should designers elect to incorporate manually actuated boom and antenna deployment mechanisms in lieu of automatic drive units, planned EVA could be used for sensor/system deployment/retraction across the total ATL program.

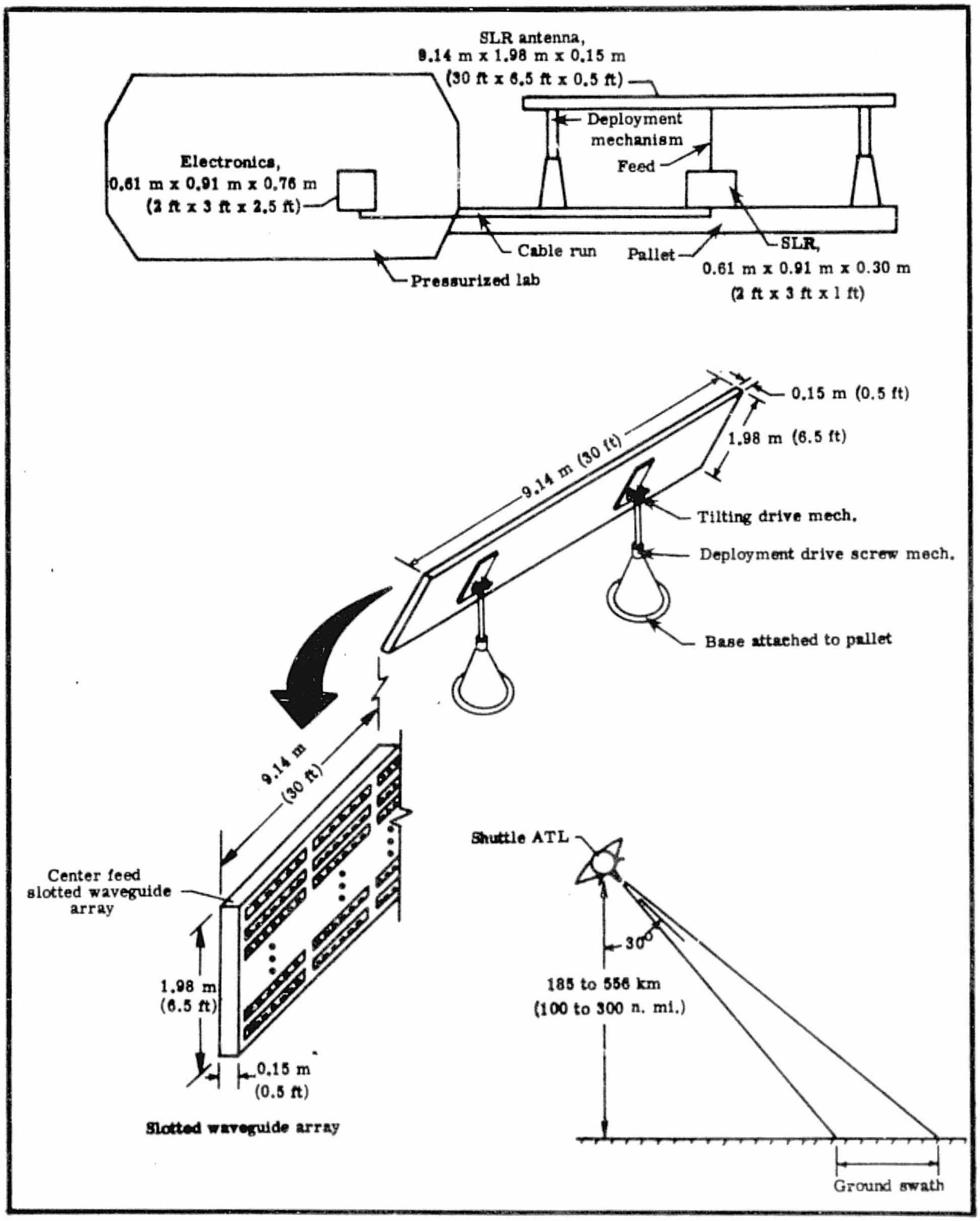

FIGURE 2.2-7: Imaging Radar Experiment--Pallet Equipment

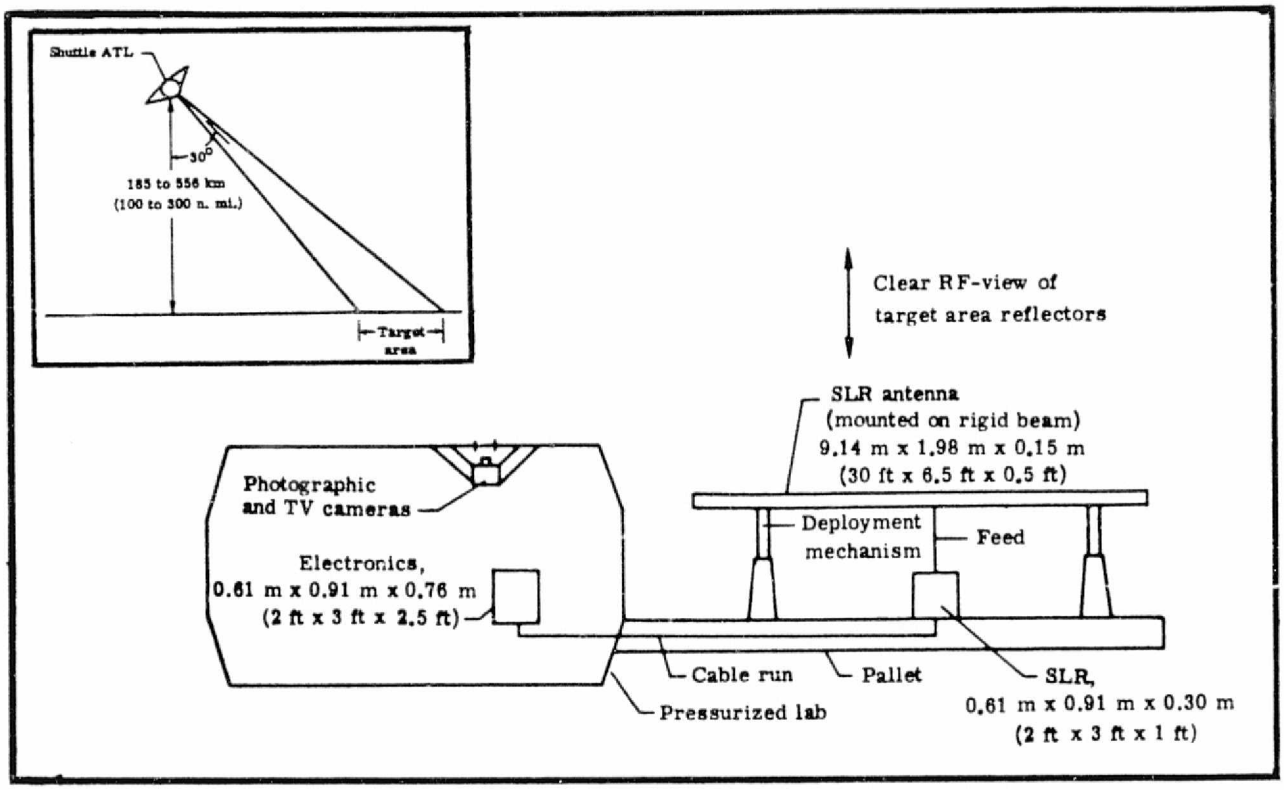

FIGURE 2.2-8: Search and Rescue Aids Experiment--Pallet Equipment

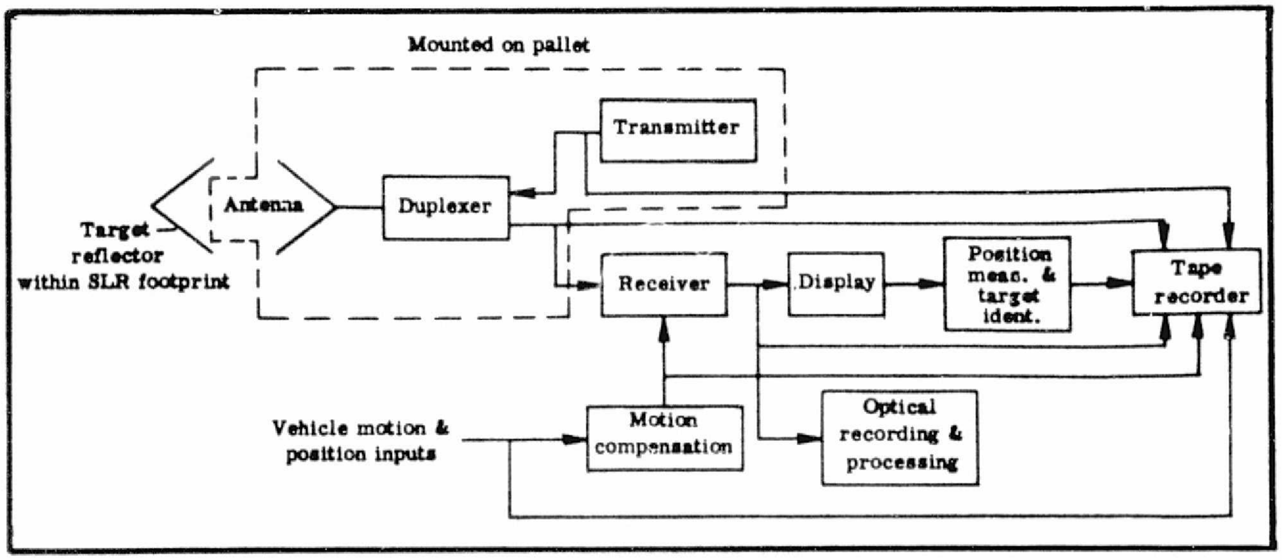

FIGURE 2.2-9: Side Looking Radar (SLR) Block Diagram (Simplified)

2.2.2.4 Integrated Real-Time Contamination Monitor--XST-044

The integrated real-time contamination monitoring experiment configuration relative to EVA application consists of a black box assembly on the ATL pallet. The assembly consists of experiment components including a mass spectrometer, optical module, particle spectrometer, optical effects module, multiplexer, decoders, filters, optics, etc. required to conduct the ATL contamination experiments (Ref. Figure 2.2-3).

Potential EVA applications may consist of black box retrieval following a malfunction for repair inside the pressurized laboratory or complete unit replacement from a spares depot.

2.2.2.5 Environmental Effects on Non-Metallic Materials--XST-029

The XST-029 experiment consists of two exposure arrays containing elastomers, coatings, and polymeric film samples sealed within vacuum tight containers. Upon test initiation, the array panels are deployed from the ATL pallet by a single 15.2 m. (50 ft.) extendible boom, Figure 2.2-10. When the boom is fully extended, the samples are unsealed and exposed to the space environment by mechanically removing covers from the array containers. The experiment is completely passive following cover removal. Prior to reentry the array containers are resealed, the boom retracted and the samples maintained in vacuum stowage until delivered to ground laboratories for analysis.

The XST-029 experiment pallet mounted components include exposure arrays (2), vacuum stowage containers, mechanical deployment/retraction mechanisms, tape recorders, and supporting electronics. The role of man in the experiment requires only the activation of the deployment boom and sample exposure mechanisms and periodic temperature readout at specific points during the mission.

EVA could be applied in each of the three EVA applications categories (unscheduled, contingency and potential planned) based on equipment design and/or on-orbit system malfunction. Unscheduled or contingency EVA can be performed

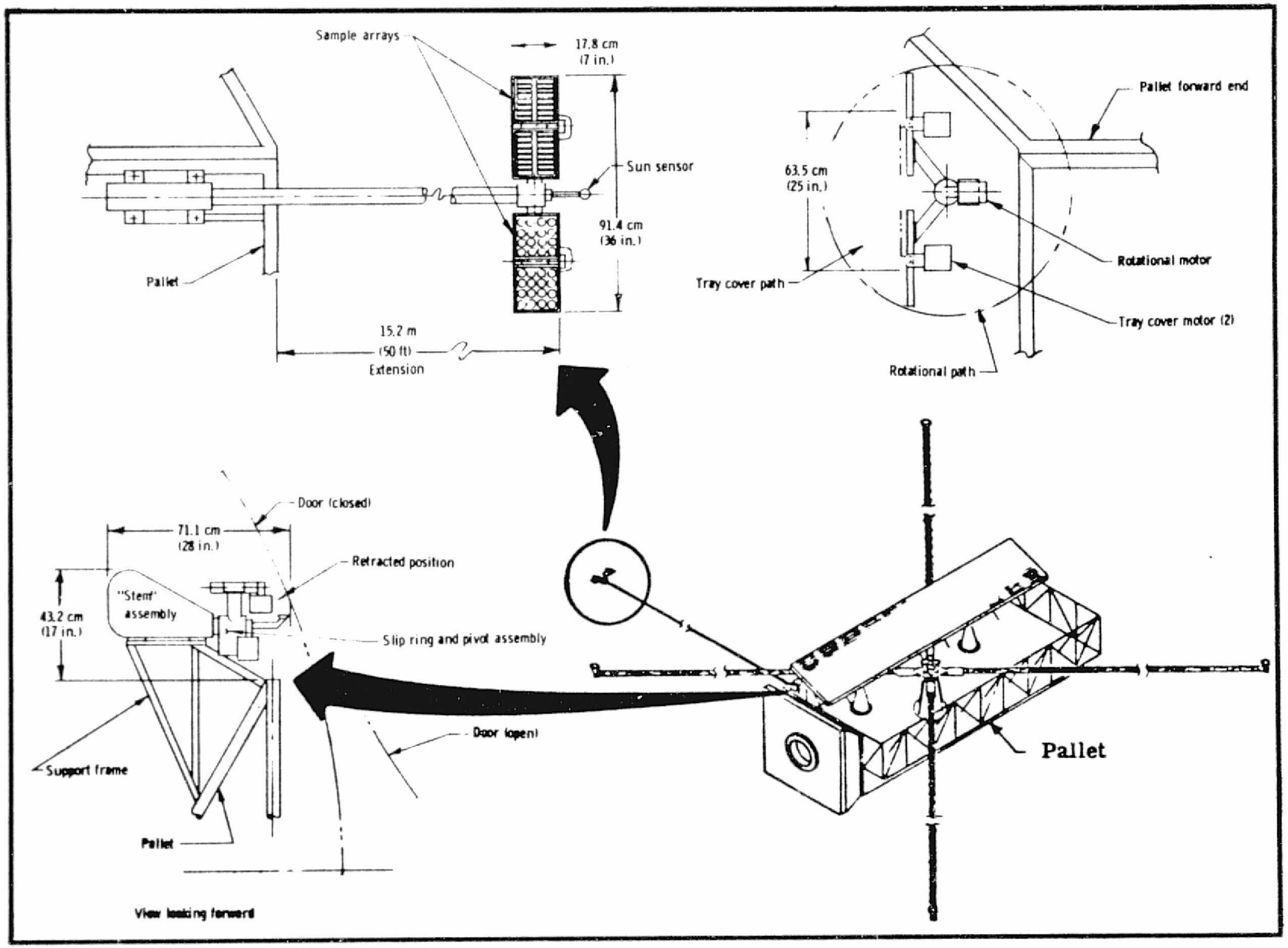

FIGURE 2.2-10: Environmental Effects on Non-Metallic Materials

to repair the deployment boom, retrieve the exposure samples, or jettison the boom if failed in the extended position. Potential planned EVA could be conducted to extend and retract a manually actuated boom, thereby eliminating an automated system.

2.2.3 ATL EVA Task Description

2.2.3.1 Planned EVA

The ATL Mission 11 conceptual design studies are depicting all pallet mounted experiment equipment to be automated and operated from the pressurized laboratory. No planned EVA functions are identified in the ATL conceptual designs as of early 1976.

2.2.3.2 Unscheduled and Contingency EVA

The Advanced Technology Laboratory, consistent with most Shuttle payloads, specifies the use of "contingency" EVA in the event of equipment malfunction or damage. (Contingency EVA as defined by the NASA Marshall Space Flight Center Space Shuttle Payload Description (SSPD) documents includes all EVA operations outside the Orbiter cabin excluding only planned EVA.) Analysis of the ATL payload discloses several automatically actuated subsystems in which a simple electrical or mechanical failure would render the total experiment completely inoperable. Failure of an extended boom or antenna would require the system to be jettisoned to enable payload bay door closure and Orbiter reentry. Assuming a second order failure, the malfunction of a jettison mechanism or entanglement of booms with surrounding equipment during jettison would necessitate a contingency EVA to ensure safe crew and Orbiter return. Relative to ATL equipment on-orbit malfunction, EVA can be employed to return the experiments to operational status or retrieve experiment sample/equipment for return to earth. Typical ATL EVA tasks are identified in Table 2.2.2 based on hypothetical payload conditions.

The Shuttle Orbiter provides EVA support equipment and expendables to conduct two, two-man EVA's of 6 hours duration each on every Shuttle flight. The EVA

TABLE 2.2.2: ATL EVA Task Identification

UNSCHEDULED EVA	CONTINGENCY EVA	POTENTIAL PLANNED EVA
INTERFEROMETER BOOM • Release and unfold interferometer boom canisters • Replace helicone antennas • Release interferometer booms and assist deployment • Manually deploy failed boom • Replace boom and boom canister element • Unjam boom • Inspect and monitor operation • Assist boom retraction and stow for reentry AUTONOMOUS NAVIGATION • Replace telescope/components • Service experiment components IMAGING RADAR AND SEARCH AND RESCUE AIDS • Release antenna hold-downs • Deploy antenna • Replace/service side-looking radar	INTERFEROMETER BOOM • Retract boom • Engage locking mechanism • Jettison failed boom • Sever interferometer boom and jettison clear of Orbiter IMAGING RADAR AND SEARCH AND RESCUE AIDS • Retract antenna • Engage locking mechanisms • Jettison antenna ENVIRONMENTAL EFFECTS • Retract boom • Engage locking mechanism • Jettison antenna • Sever boom and jettison clear of Orbiter	MICROWAVE INTERFEROMETER NAVIGATION AND TRACKING AIDS • Deploy booms - Release boom canister - Deploy (unfold) boom canisters - Release interferometer booms - Assist boom deployment • Stow booms - Reverse above operations IMAGING RADAR AND SEARCH AND RESCUE AIDS • Deploy antennas - Release antenna hold-downs - Manually deploy antennas • Stow antennas - Reverse above operations ENVIRONMENTAL EFFECTS ON NON-METALLIC MATERIALS • Manually deploy and retract boom

TABLE 2.2.2: ATL EVA Task Identification (continued)

UNSCHEDULED EVA	CONTINGENCY EVA	POTENTIAL PLANNED EVA
• Repair: – Tilting drive mechanism – Antenna deploy drive – Antenna • Replace electrical cables • Remove debris • Stow antenna CONTAMINATION MONITOR • Replace entire "black-box" assembly • Connect/disconnect electrical cable(s) ENVIRONMENTAL EFFECTS • Release launch locks • Manually deploy/retract boom • Retrieve sample arrays • Close sample array containers • Replace boom		

capability is available at no cost to the payloads. A third EVA capability is provided but reserved on each Shuttle flight for Orbiter contingency or rescue operations, if required. Additional EVA capability for payload use can be provided as payload chargeable equipment. For the ATL payload, in which several experiments deploy hardware (booms, antennas) once at mission initiation and retract the hardware only at mission termination, EVA appears highly applicable for replacing automatic deployment systems.

2.2.3.3 Potential Planned EVA

Potential planned EVA can be defined as candidate EV operations that could be performed if the man-machine interfaces were designed for on-orbit servicing/operation. The deployment and retraction of ATL booms and antennas can be performed by EV crewmen using a simple, geared hand crank or ratchet mechanism. Significant cost savings appear feasible from initial ATL design through orbital operation. The replacement of automated deployment mechanisms and their associated backup, status and safety subsystems with manually actuated hardware should be a prime consideration in ATL payload planning and design. Table 2.2.2 lists ATL potential planned EVA tasks based on the utilization of EVA and baseline EV support equipment to replace automated hardware deployment systems.

2.2.3.4 Task Definition

Analysis of the ATL Mission 11 payload resulted in the identification of representative tasks within the capabilities of the EVA crewman and support system technology. The tasks listed in Table 2.2.2 are typical of the twelve classifications described in Table 2.1.1 and require specific and sub-tasks for completion. The tasks are intended to illustrate a significant range of EVA capabilities available to the payload community and not a critical design review of the payload or associated support systems. EVA task outlines are developed in the following subsections to define major task requirements, sub-task classifications, and ancillary information. Typical EVA tasks are selected to develop representative EVA mission scenarios. Preliminary procedures and timelines are developed in Sections 2.2.5 and 2.2.6 of this report.

2.2.4 ATL EVA Mission Scenarios

The ATL development program identified candidate experiments for Shuttle flight early in the program definition phase. However, the selection of experiments, structural configuration, and experiment orientation/location in the payload bay have not been firmly established for the candidate flights. Only conceptual experiment configurations (preliminary) are currently available. No planned EVA operations are presently being specified.

Two hypothetical EVA missions were defined from the ATL (Mission 11) tasks identified in Table 2.2.2. Several separate tasks were combined into a typical payload EVA servicing mission based on the representative ATL tasks. ATL EVA mission scenario number 1 assumes a malfunction of the launch lock on one of the four interferometer boom canisters, thus damaging the boom canister linkage and boom deployment mechanism during attempted boom extension. In order to conduct the experiment, an EVA is necessary to release the launch lock, remove the damaged canister linkage, deploy the boom canister and assist extension of the receiving antenna boom. The major tasks involved and task performance rationale are contained in Table 2.2.3. The second ATL mission scenario is predicated on the payload being designed to employ manual devices for actuating deployable subsystems. The ATL mission 11, as currently planned, contains the following pallet mounted experiments which incorporate extendible mechanisms:

- Microwave Interferometer Navigation and Tracking Aid
- Imaging Radar
- Search and Rescue Aids
- Environmental Effects on Non-Metallic Materials.

The major extravehicular activities would involve releasing launch lock mechanisms and manually deploying various extendible structures at experiment initiation and configuring the experiment hardware for reentry/landing at experiment completion. Other EV activities associated with the UV Meteor

TABLE 2.2.3; ATL EVA Tasks--Mission Scenario No. 1

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
INTERFEROMETER BOOM RELEASE AND DEPLOYMENT	Perform a two-man "unscheduled" EVA to restore experiment to operational status and avoid necessity to relaunch experiment	Structural damage during launch, debris jam, malfunction in actuation mechanism, etc.
• Egress airlock and translate to worksite	Crew translation using handrails over Spacelab module	Requires crew mobility aids to worksite
• Inspect and diagnose	Determine cause of malfunction, repair requirements, tools and ancillary support equipment	Crew tether point required for stabilization; access to work area
• Translate to tool/spares stowage	Retrieve support equipment and tools	Requires portable workstation, pry bar, hand tools
• Transfer repair gear to worksite	Hand carry repair equipment to worksite	Equipment tethered to translating crewman
• Deploy workstation and equipment	Attach/deploy equipment and ingress portable workstation	Requires portable workstation interface or "universal" attachment fixtures
• Remove launch lock/linkage	Perform required repair/refurbishment operations	Use two EV crewmen as required
• Deploy boom canister	Relocate EVA workstation and manually position interferometer boom canister	Requires mobility aids and portable workstation attachment provisions

TABLE 2.2.3: ATL EVA Tasks--Mission Scenario No. 1 (continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
• Boom deployment/ monitor	Monitor interferometer boom canister door release and assist deployment if required	Assumes interferometer boom deployment subsystem is operational
• Repair/replace launch lock/linkage	Repair linkage/launch lock at payload bay stowage/repair station	Confirm microwave interferometer experiment operational before proceeding with repairs
• Replace launch lock and linkage	Refurbish boom canister deployment system to operational status	Use two EVA crewmen
• Remove portable workstation and support equipment	Remove all supporting equipment at worksite	Reverse of installation operations
• Stow EVA support equipment	Return and stow all EVA support items	Requires two trips for one EV crewman
• Translate to and ingress airlock		<u>TASK COMPLETE</u>

Spectroscopy, Autonomous Navigation, and Lidar Measurements experiments would include contamination container venting, contamination cover removal, launch lock disengagement, and visual inspection. The primary tasks are listed and task performance rationale provided in Table 2.2.4.

2.2.5 ATL EVA Task Completion Plans--Mission Scenario No. 1

The EVA task completion plans (Task 4 of the contract) provides a preliminary set of procedures and timelines to demonstrate that the selected EVA payload tasks can be accomplished by application of the Shuttle EVA system. The task completion plans delineate major elements of the EVA mission and the extravehicular mission support requirements including number of crewmen, EVA mission time, translation aids and location, restraints and tools.

Preliminary timelines and procedures developed for the ATL mission scenario no. 1 (i.e., unscheduled EVA to release/deploy the Interferometer Navigation and Tracking Aid booms) are provided in Table 2.2.5. Assumptions associated with the mission scenario include the following:

- Sufficient mobility aids (handholds, handrails) are provided by the payload and/or Shuttle Orbiter to access the Spacelab pallet from the airlock.
- Realizing the possible requirement for an unscheduled EVA, crew mobility aids are provided by the payload for access to each pallet mounted ATL experiment.
- Since design details are not available for many of the ATL pallet mounted subsystems, conceptual designs were developed by the contractor to implement procedures development.
- Two qualified crewmembers are available for conducting EVA. A third crewmember is available to perform minimal Payload Station (PS) EV supporting functions.

TABLE 2.2.4: ATL EVA Tasks--Mission Scenario No. 2

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
DEPLOY ATL (MISSION 11) PALLET MOUNTED EXPERIMENT SUBSYSTEMS	Experiment subsystems must be designed for on-orbit manual operation to conduct EVA mission. All experiment operations requiring deployment are performed by EVA.	Economically justified in experiment/payload development and launch programs
1. INTERFEROMETER BOOM DEPLOY		
• Egress airlock; translate to equipment stowage	Crew translation/tool transport across/around Spacelab module	Requires crew mobility aids to worksites
• Ingress foot restraints and unstow support hardware	Retrieve tools and task support hardware (Foot restraints are permanently mounted at stowage area.)	Support hardware is part of payload launched equipment
• Translate to worksite and ingress EVA workstation	Stow/restrain/position support hardware, unfold and ingress workstation	Portable EV workstation is launched at first worksite (1 only)
• Deploy boom canisters	Unlock launch latches and pivot canister to locked position (4 boom canisters)	4 booms with 1 latch each; requires mobility aids/handholds
• Deploy booms	Unlatch antenna stowage locks (1 per boom); attach ratchet handle; deploy 4 booms simultaneously	Booms deployed from workstation

TABLE 2.2.4: ATL EVA Tasks--Mission Scenario No. 2 (continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
• Monitor during check-out	One EV crewman standby for interferometer checkout, other crewman transfer to next worksite	
• Retrieve workstation and equipment; transfer to next worksite	Disengage EV workstation, unstow tools and translate to Imaging Radar--Search and Rescue Aids experiment	
2. IMAGING RADAR AND SEARCH AND RESCUE ANTENNA DEPLOY		
• Attach, deploy and ingress portable EV workstation	Setup worksite for antenna positioning and deployment; (first EV crewman has previously ingressed second EV workstation)	EV operations require two crew workstations, one is launched in place at experiment
• Position antenna	Unlock and pivot antenna from stowed into deploy position (2 crewmen)	Requires a crewman at stand-offs near each end of antenna
• Deploy antenna	Use jack screw type telescoping unit to deploy antenna above doors into operating position	Tool interface on experiment hardware; ratchet type actuation mechanism
• Monitor during check-out	First EV crewman standby for experiment checkout, second crewman transfer to Environmental Effects experiment with portable workstation and required tools	NOTE: From this point EV crewmen perform separate tasks simultaneously

TABLE 2.2.4: ATL EVA Tasks--Mission Scenario No. 2 (continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
• Retrieve workstations and equipment; transfer to next worksite	First crewman translate to area of three remaining pallet experiments	
3. <u>ENVIRONMENTAL EFFECTS BOOM DEPLOY</u>		
• Attach, deploy and ingress portable workstation	Setup worksite for boom deployment and experiment cover activation (covers are not removed until experiment is fully deployed to avoid "near vehicle" contamination)	First EV crewman performs worksite operations (cover deployment only requires switch actuation)
• Deploy boom	Use ratchet gear drive mechanism to deploy boom	Ratchet handle identical for all deployment operations (2 required)
• Deploy cover	Actuate switch to deploy experiment covers; confirm cover open status	
• Return to equipment stowage area	Replace tools and support equipment to stowage and secure	Leave EV workstation for second EVA to configure experiment for reentry
4. <u>UV METER SPECTROSCOPY</u>		
• Attach, deploy and ingress portable workstation	Prepare worksite to vent contamination container; remove and stow contamination cover	Second EV crewman performs these experiment tasks
• Vent contamination containers	Actuate vent device	Simple mechanical device on both experiments

TABLE 2.2.4: ATL EVA Tasks--Mission Scenario No. 2 (continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
• Remove and stow covers	Release cover retainers and stow unit	One-man operations
5. <u>AUTONOMOUS NAVIGATION</u>		
• Repeat steps in item 4 above	Perform operations similar to UV Meter Spectroscopy	One-man operations
6. <u>LIDAR MEASUREMENT OF CIRRUS CLOUDS</u>		
• Repeat steps in item 4 above	Perform operations similar to UV Meter Spectroscopy	One-man operations
• Return to equipment stowage area	Replace tools and support equipment to stowage and secure	Leave EV workstation for second EVA to configure experiment for reentry
• Transfer to and ingress airlock		<u>MISSION COMPLETE</u>

TABLE 2.2.5: ATL Task Compeltion Plans -- Mission Scenario No. 1

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Interferometer Boom Release and Deployment | MODE: Unaided EVA | Sheet 1 of 6

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
		1.0 Prepare for unscheduled two-man EVA to service/deploy malfunctioned interferometer boom					
4.5	4.5	1.1	Egress airlock and translate to worksite; stabilize at worksite	Egress airlock and translate to worksite; stabilize	Payload Station: payload bay lighting as required	Exterior of airlock, transfer tunnel, Spacelab module and pallet	*Requires approx. 12 m. (40 ft.) of EVA handrail --payload chargeable
16.5	12.0	1.2	Inspect equipment and diagnose problem	Inspect equipment and diagnose problem; determine equipment/tool requirements		Pallet and interferometer boom mount	*Requires 3 portable EVA handholds (assume handrails for boom access are installed prior to launch as a backup measure)
18.0	1.5	1.3	Formulate repair approach	Translate to tool/support equipment stowage locker; ingress foot restraints		Orbiter handrails and stowage locker	Foot restraints (1 set) provided at stowage locker
20.5	2.5	1.4	Same as above	Retrieve portable EV workstation and 3 portable handholds; tether equipment to EMU and return to worksite		EMU tether	*Requires 1 portable EVA workstation and 3 portable handholds at worksite
23.5	3.0	1.5	Deploy EVA workstation, handholds; ingress workstation	Return to stowage area; retrieve socket set (with ratchet), pry bar, combination wrench set, 3 equipment tethers, magnetic parts retainer and carry-all container		Spacelab pallet	*Requires tool sets: • 3/8" drive socket set • combination open/box end wrench set • magnetic parts retainer • 24" pry bar • carry-all container

*EVA items/equipment required to complete ATL Mission Scenario No. 1; to be provided by payload.

TABLE 2.2.5: ATL Task Completion Plans -- Mission Scenario No. 1 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Interferometer Boom Release and Deployment

Sheet 2 of 6

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
24.0	0.5	1.6	Same as above	Translate to worksite and stow/restrain tools		Spacelab pallet	CM2 stabilizes using handholds and handrails
24.0	24.0						
		2.0 Boom launch lock and boom storage canister linkage removal/replacement					
3.5	3.5	2.1	Remove upper and lower bolts from damaged linkage	Assist CM1: capture bolts with magnetic retainer and stow		Payload experiment equipment	EV crewman required to remove bolts from captive lock nuts (SEE FIG. 2.2-13)
4.0	0.5	2.2	Remove linkage	Assist CM1: caddy tools, tether and secure linkage to structure		Same as above	SAFETY NOTE: Assure no stored energy in linkage mechanism
4.5	0.5	2.3	Remove electrical connector from boom canister launch lock	Assist CM1: NOTE MISALIGNMENT OF LAUNCH LOCK RELATIVE TO OTHER THREE		Electrical connector housing	Twist type electrical connector (NOTE MISALIGNMENT)
9.0	4.5	2.4	Remove four bolts from launch lock	Assist CM1: caddy tools, capture bolts on magnetic retainer		Interferometer boom mount	Lock nuts are captive
9.3	0.3	2.5	Remove canister launch lock	Assist CM1: tether launch lock		Launch lock mechanism	

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TABLE 2.2.5: ATL Task Completion Plans -- Mission Scenario No. 1 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Interferometer Boom Release and Deployment

Sheet 3 of 6

TIME (Min.) CUM.	TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	EVA CM2	OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
10.8	1.5	2.6	Inspect passive launch lock interface on canister	Inspect launch lock			
11.3	0.5	2.7	Deploy boom canister to operational position	Deploy boom canister		Interferometer boom	Manual operation
14.3	3.0	2.8	Monitor interferometer boom deployment (first 3.0 minutes)	Monitor boom deployment: assist as required	Payload Station: deploy interferometer boom		Boom deployment requires 25 min. (4 booms deploy simultaneously)
17.3	3.0	2.9	Inspect canister launch lock for damage	Monitor boom deployment			No visible launch lock damage or debris
22.3	5.0	2.10	Replace launch lock (secure with two bolts only--diagonal corners)	Assist CM1			Secure with two bolts for testing
22.8	0.5	2.11	Replace electrical connector	Monitor boom deployment			
25.8	3.0	2.12	Monitor launch lock operation	Monitor launch lock operation	Payload Station: actuate launch lock switch --cycle 6 times		Launch lock operational FAILURE RATIONALE: Launch loads on boom canister skewed boom lock preventing release.
28.8	3.0	2.13	Replace remaining launch lock bolts, align and secure	Assist CM1			Align by referencing other 3 launch locks

TABLE 2.2.5: ATL Task Completion Plans -- Mission Scenario No. 1 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Interferometer Boom Release and Deployment

Sheet 4 of 6

TIME (Min.) CUM.	TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	EVA CM2	OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
30.8	2.0	2.14	Monitor launch lock operation--confirm	Continue boom deployment monitoring	Payload Station: actuate launch locks--cycle 2 times		Final launch lock checkout
32.3	1.5	2.15	Translate to tool/support equipment stowage locker	Same as above			
34.8	2.5	2.16	Retrieve spare boom canister linkage and translate to worksite	Prepare for canister linkage rod installation			Limited spares available for critical item replacement
35.8	1.0	2.17	Ingress workstation and prepare for canister linkage rod installation	Confirm interferometer boom deployment			Return interferometer subsystem to operational status
41.3	5.5	2.18	Install spare canister linkage	Assist CM1		Interferometer boom mount	
65.3	41.3						
		3.0 Inspect pallet mounted experiment equipment for damage and monitor experiment deployment					
10.0	10.0	3.1	Translate to and inspect Imaging Radar and Search and Rescue Aids pallet mounted equipment	Same as CM1		Imaging Radar and Search and Rescue Aids equipment	

TABLE 2.2.5: ATL Task Completion Plans -- Mission Scenario No. 1 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Interferometer Boom Release and Deployment

Sheet 5 of 6

TIME (Min.) CUM.	TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	EVA CM2	OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
25.0	15.0	3.2	Monitor antenna positioning and deployment	Same as CM1: confirm antenna deployed	Payload Station: deploy antenna to operational position		
37.0	12.0	3.3	Inspect for damage: • UV Meteor Spectroscopy • Autonomous Navigation • Lidar Measurements	Assist CM1: confirm no damage		Experiment structural exterior	Experiments located in same general area on pallet
39.0	2.0	3.4	Translate to Environmental Effects experiment and stabilize	Translate to Environmental Effects experiment and stabilize		Spacelab pallet and Orbiter handrails	
42.0	3.0	3.5	Inspect for damage	Same as CM1: confirm no damage		Experiment external structure	
47.0	5.0	3.6	Monitor sample boom deployment and cover container	Confirm boom and cover actuation	Payload Station: deploy antenna boom and sample cover		Samples are contamination-sensitive
49.0	2.0	3.7	Translate to initial EVA worksite	Translate to initial EVA worksite			Interferometer worksite
114.3	49.0						
		4.0	Prepare for and terminate EVA mission				
3.0	3.0	4.1	Ingress EV workstation and	Place tools and support			Recover tools for stowage

TABLE 2.2.5: ATL Task Completion Plans -- Mission Scenario No. 1 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Interferometer Boom Release and Deployment

Sheet 6 of 6

TIME (Min.) CUM.	TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	EVA CM2	OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
			retrieve tools and support equipment	equipment in carry-all pouch			in locker
5.0	2.0	4.2	Egress workstation and detach workstation from pallet	Translate to tool/support equipment stowage locker; ingress foot restraints; stow equipment			Stow and secure tools/equipment for reentry
7.0	2.0	4.3	Translate to stowage locker and ingress foot restraints	Egress foot restraints and standby			
8.5	1.5	4.4	Stow portable workstation and secure locker	Assist CM1: confirm locker secure			
12.0	3.5	4.5	Translate to airlock and ingress	Translate to airlock and ingress		Pallet, Spacelab module, transfer tunnel and airlock exterior	EVA OPERATIONS COMPLETE
126.3 ↑ TOTAL EVA TIME	12.0						

TOTAL EVA TIME: 2 hrs., 6 min.

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- Limited ATL spare components are provided for pallet mounted equipment. The spares are stowed in a locker attached to the pallet structure.
- Foot restraints (1 pai.) and mobility aids are provided at the spares stowage locker.
- Sufficient pallet lighting is provided by the Orbiter and payload to perform EV tasks.

Mobility aid placement for accessing the ATL pallet from the external airlock is depicted in Figure 2.2-11. Provisions for the EVA crewman to translate from the airlock hatch, up the Spacelab end cone, over the module, down the aft cone, and along the pallet are incorporated in the Spacelab design. The pallet is sufficiently flexible to allow installation of handrails (and foot restraints) as required for each mission (Ref. 2.2.5). The quantity of handrail in excess of that provided as baseline equipment by the Shuttle Orbiter and Spacelab is estimated to be 12 m. (40 ft.). The handrail would be installed prior to launch (previous assumption) as a backup capability to ensure payload mission success, Figure 2.2-12.

The ATL mission scenario no. 1 is predicated on the removal of launch lock and mechanical linkage mechanisms to restore the experiment to operational status. Detail design of the ATL hardware items was not available during this study--for many items, conceptual designs were also not available. However, hardware concepts were developed by this study to depict representative types of EV operations and crewman interfaces that may be encountered. ATL launch lock and linkage concepts are provided in Figure 2.2-13 in order to illustrate the level of EV tasks and clarify the payload operational requirements. The hardware concepts are not intended to influence final component design.

EVA support equipment in addition to the present Shuttle accommodations will be required to accomplish the unscheduled payload repair functions. The additional support items consist of smaller hand tools and restraint

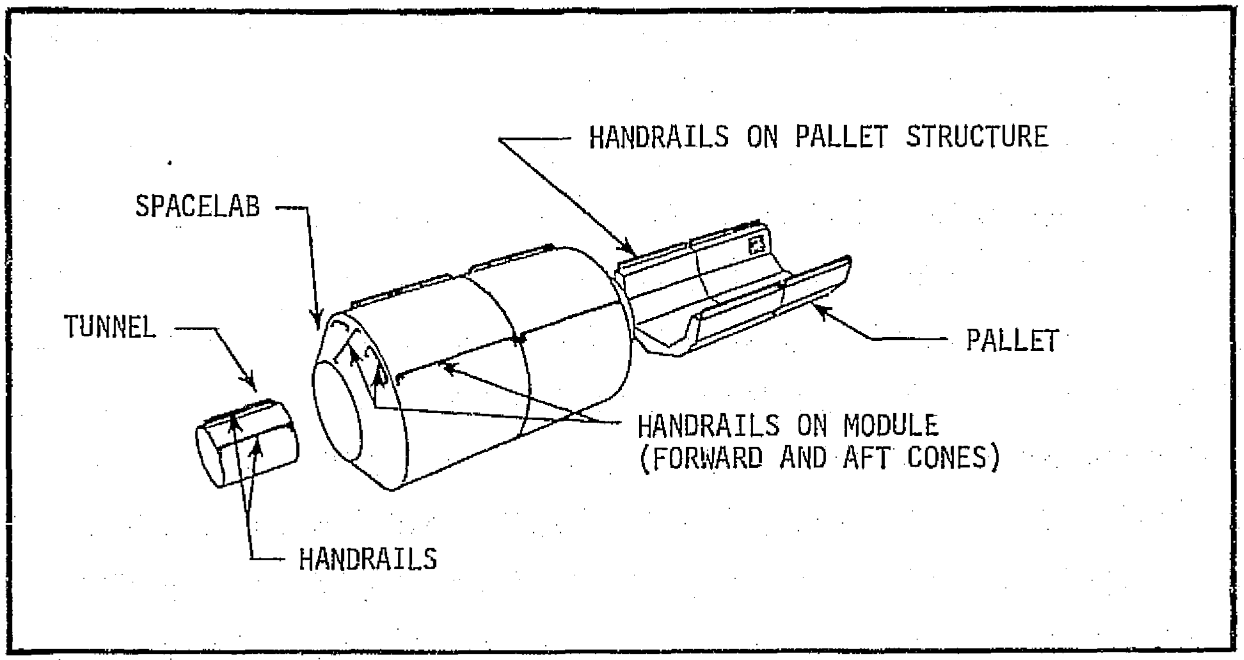

FIGURE 2.2-11: EVA Mobility Aids Provided by Spacelab (Concept)

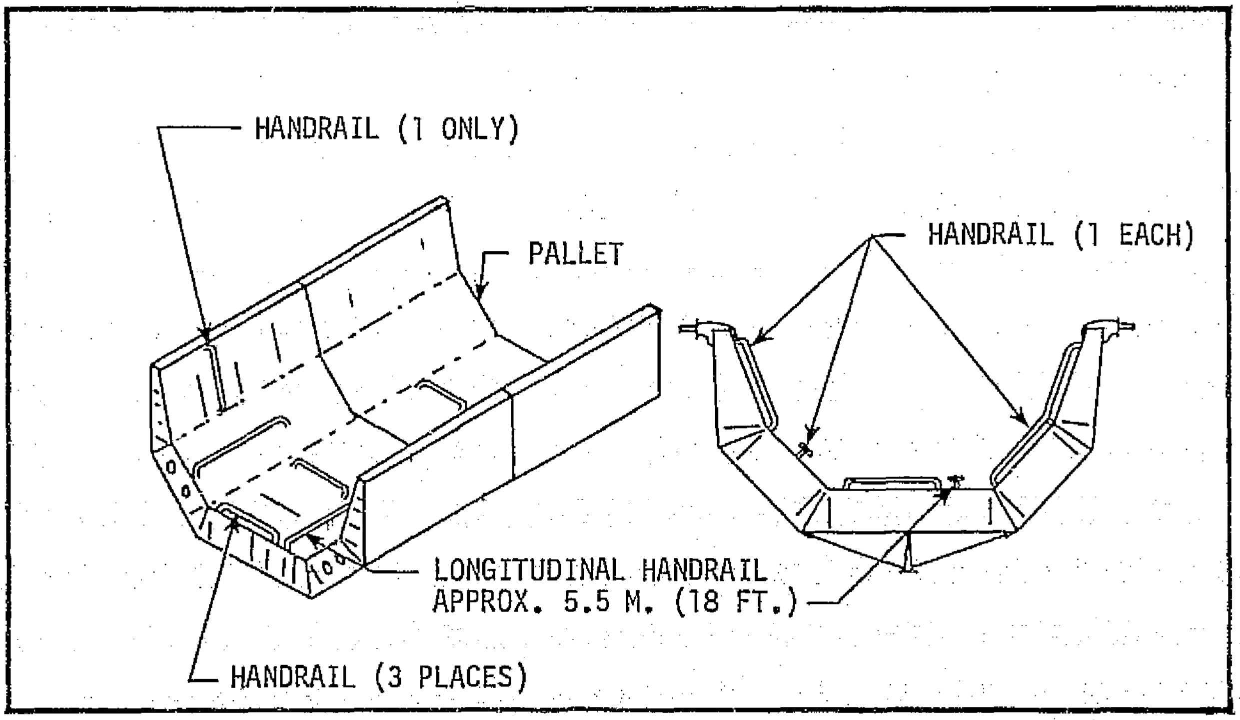

FIGURE 2.2-12: Additional EVA Handrail Required by ATL (Concept)

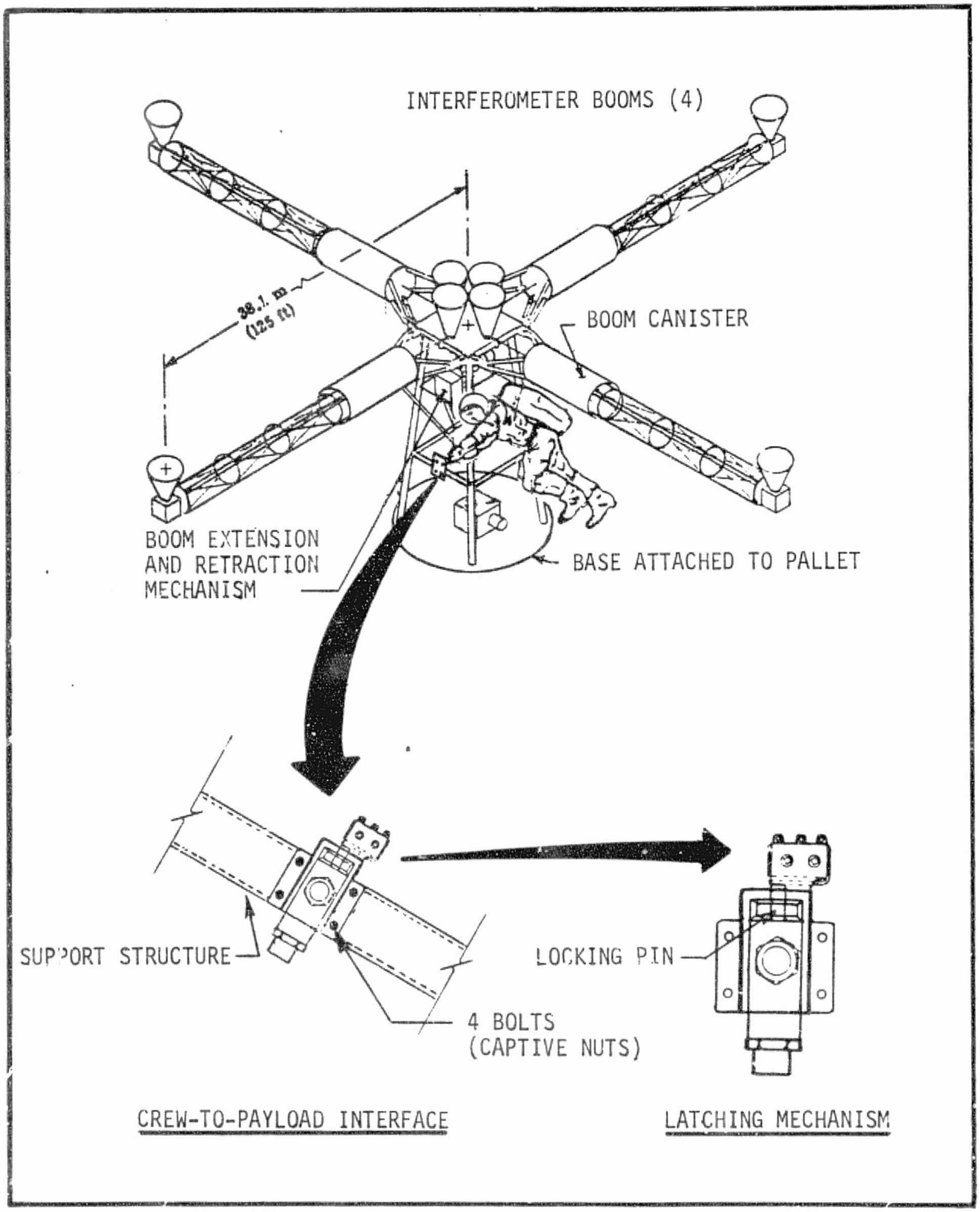

FIGURE 2.2-13; Conceptual Layout of Interferometer Hardware--EVA Interfaces

articles listed below:

- Portable EVA workstation with restraint fittings--1 required
- Portable EVA handholds--3 required
- Equipment/crew tethers--3 required
- Pry bar, 24 in.--1 required
- EVA handrail -- approximately 12 m. (40 ft.)
- Wrench set, mechanics 5-piece combination open and box end--1 required
- Magnetic parts retainer--1 required
- Small items carry-all container--1 required.

The additional support items required to perform each EVA mission scenario developed by the study are provided in Section 3.0, Tables 3.3.2 through 3.3.10 of this report.

2.2.6 ATL EVA Task Completion Plans--Mission Scenario No. 2

The Advanced Technology Laboratory EVA mission scenario no. 2 is based on the replacement of automated experiment deployment systems with simple man-machine interfaces/mechanisms for manual operation. Each experiment would initially be designed (or modified) for on-orbit EVA servicing using either manual or power assisted hand tools. The experiments would provide "standard" tool interfaces to minimize special tool requirements and quantity. The hypothetical EVA mission deploys and retracts the extendible members at experiment initiation and termination, respectively, for the following experiments:

- Microwave Interferometer Navigation and Tracking Aid
- Imaging Radar and Search and Rescue Aids
- Environmental Effects on Non-Metallic Materials.

The Environmental Effects on Non-Metallic Materials experiment incorporates

a motor driven sample exposure module in addition to a 15.2 m. (50 ft.) extendible boom. To avoid sample contamination, the sample exposure module will remain automated and be actuated from the crew cabin only with the boom in the fully deployed position.

Additional EV functions supporting the manually deployed ATL experiments concept include contamination container venting, cover removal, and launch lock release for the following experiments on ATL Mission 11:

- UV Meteor Spectroscopy
- Autonomous Navigation
- Lidar Measurements.

The above experiments would require only the replacement of automatic latching/locking and venting mechanisms with manually actuated units.

The primary EVA tasks for ATL mission scenario no. 2 are outlined in Table 2.2.4 including EVA task performance rationale. The EVA task completion plans, shown in Table 2.2.6, provide a preliminary set of timelines and procedures to initially configure the experiments for orbital operation and for termination prior to reentry. The task completion plans delineate major EVA functions and hardware required to perform the mission including EVA task time, operational mode, translation aids and locations, restraints and tools. Assumptions and guidelines associated with the mission scenario include the following:

- The ATL experiment hardware is specifically designed for on-orbit EVA operation.
- Although "hand-held" power tools for boom/antenna deployment may be applicable, only manually actuated devices are used to demonstrate fundamental EVA capabilities.
- Crew translation aids are provided at all required locations by the payload for EVA functions.

TABLE 2.2.6: ATL Task Completion Plans -- Mission Scenario No. 2

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Deploy ATL (Mission 11) Pallet Mounted Experiment Subsystems MODE: Unaided EVA Sheet 1 of 10

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
			1.0 Initiate EVA to configure ATL for orbital operations				
4.5	4.5	1.1	Egress airlock and translate to equipment stowage	Egress airlock and translate to interferometer base structure	Payload Station: observe EVA functions if required	Handrails and equipment stowage locker	Interferometer base structure mounted directly to pallet
7.5	3.0	1.2	Ingress stowage locker foot restraints and retrieve boom deployment tools	Inspect interferometer for deployment readiness		Interferometer boom structure	Inspect for launch damage
10.0	2.5	1.3	Tether tools to EMU and translate to interferometer boom structure	Same as above			
10.0	10.0						
			2.0 Unlock and deploy interferometer booms				
5.5	5.5	2.1	Ingress interferometer boom deployment workstation and engage hand tool	Unlock launch lock on each boom canister (4 latches)		Handrails and launch locks	Handrails are provided to access each launch lock. Portable EVA foot restraints are provided at first EV worksite only and are transferred as required.

TABLE 2.2.6: ATL Task Completion Plans -- Mission Scenario No. 2 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Deploy ATL (Mission 11) Pallet Mounted Experiment Subsystems

Sheet 2 of 10

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
12.0	6.5	2.2	Deploy boom stowage canisters to antenna extension position	Complete launch lock release prior to deploying boom canisters; stabilize clear of boom canisters and monitor deployment	Payload Station: monitor deployment	Interferometer boom	Boom stowage canisters are deployed approx. 80° from the stowed position prior to antenna deployment. Hand tools and canister deployment drive train allow both rotary and push-pull (ratchet) motions.
14.5	2.5	2.3	Complete boom canister deployment, disengage and tether hand tool	Translate to boom canisters (4) and confirm complete deployment			
16.0	1.5	2.4	Engage boom canister, position lock pin in deployment drive linkage	Same as above	Payload Station: acknowledge boom canisters deployed	Lock pin and deployment linkage	Lock pin secures canister in extended position
18.0	2.0	2.5	Remove launch pin and engage hand tool to interferometer boom extension drive train mechanism	Translate to observation point and monitor boom deployment; tether to structure		Boom extension drive mechanism	The boom stowage canister and interferometer boom deployment mechanisms are accessible from one worksite
30.0	12.0	2.6	Initiate boom extension and deploy approx. 15.2 m. (50 ft.) of boom	Monitor boom deployment			All booms deploy simultaneously; use combination of rotary and push-pull motion (see Figure 2.2-14)

TABLE 2.2.6: ATL Task Completion Plans -- Mission Scenario No. 2 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Deploy ATL (Mission 11) Pallet Mounted Experiment Subsystems

Sheet 3 of 10

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
32.5	2.5	2.7	Exchange positions with CM2 and tether to structure	Exchange positions with CM1 and ingress worksite			Exchange tasks to avoid crew fatigue
51.0	18.5	2.8	Complete boom extension--deploy remaining 22.8 m. (75 ft.); remove and tether hand tool to EMU	Rest; monitor boom deployment	Payload Station: acknowledge booms fully deployed		
53.0	2.0	2.9	Engage launch lock pin and egress workstation	Confirm booms fully deployed; translate to equipment stowage			Launch lock pin secures boom drive mechanism in extended position
57.5	4.5	2.10	Remove workstation and translate to aft imaging radar (IR) antenna support structure	Retrieve portable foot restraints, additional hand tool and translate to forward imaging radar support structure		Imaging radar/search and rescue experiment structure	
67.5	57.5						
		3.0	Position and deploy side looking radar (SLR) antenna (Imaging Radar and Search and Rescue Aids experiment)				
1.5	1.5	3.1	Attach and deploy portable EVA workstation at aft imaging radar (IR) antenna support	Attach foot restraints at forward IR antenna support worksite		IR antenna structure	One worksite at base of each IR antenna support structure (see Figure 2.2-15)

TABLE 2.2.6: ATL Task Completion Plans -- Mission Scenario No. 2 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Deploy ATL (Mission 11) Pallet Mounted Experiment Subsystems

Sheet 4 of 10

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
4.5	3.0	3.2	Ingress workstation and inspect antenna for deployment status	Ingress foot restraints and inspect antenna for deployment status			Confirm antenna status
5.5	1.0	3.3	Release antenna aft tilting launch lock	Release antenna forward tilting launch lock			Secures antenna in stowed position during launch and reentry
12.0	6.5	3.4	Manually tilt SLR antenna	Manually tilt SLR antenna	Payload Station: voice relay tilt position on scale	SLR antenna and handholds	Use handholds provided on SLR antenna near each end; confirm position by observing scale on each end of antenna.
13.0	1.0	3.5	Release antenna aft deployment launch lock	Release antenna forward deployment launch lock		Launch lock	Secures IR deployment structure during launch and reentry
14.0	1.0	3.6	Attach hand tool to antenna aft deployment gear mechanism	Attach hand tool to antenna forward deployment gear mechanism		Antenna deployment gear mechanism	
26.0	12.0	3.7	Deploy SLR antenna; coordinate with CM2	Deploy SLR antenna; coordinate deployment with CM1			Use crewmember talkback by observing linear scale on each "telescoping" support during deployment
28.0	2.0	3.8	Confirm full extension; remove and tether hand tool to EMU	Confirm full extension; remove and tether hand tool to EMU			

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TABLE 2.2.6: ATL Task Completion Plans -- Mission Scenario No. 2 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Deploy ATL (Mission 11) Pallet Mounted Experiment Subsystems

Sheet 5 of 10

TIME (Min.) CUM.	TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	EVA CM2	OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
29.5	1.5	3.9	Unstow and insert antenna retention pin (aft deployment mechanism)	Unstow and insert antenna retention pin (forward mechanism)		Antenna deployment gear mechanism	
33.0	3.5	3.10	Egress and detach EVA workstation; tether workstation to EMU	Egress, detach and tether foot restraints to EMU	Payload Station: confirm SLR in operational status		
36.5	3.5	3.11	Translate to environmental effects experiment with EVA workstation and hand tool	Translate to equipment stowage and stow hand tool		Handrails	
104.0	36.5						
			4.0 Deploy Environmental Effects Experiment (EEE)			NOTE: TASKS 5.0 AND 6.0 ARE PERFORMED BY CM2 AS CM1 IS PERFORMING TASK 4.0.	
3.0	3.0	4.1	Attach and deploy EVA workstation at EEE worksite	See Tasks 5.0 and 6.0		Pallet structure and handholds	
7.5	4.5	4.2	Ingress workstation and inspect EEE for deployment status		Payload Station: acknowledge deployment status	EEE structure	Confirm operational status to Payload Station

TABLE 2.2.6: ATL Task Completion Plans -- Mission Scenario No. 2 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Deploy ATL (Mission 11) Pallet Mounted Experiment Subsystems

Sheet 6 of 10

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
8.5	1.0	4.3	Attach hand tool to boom gear drive mechanism	See Tasks 5.0 and 6.0			Located on aft end of boom housing
9.5	1.0	4.4	Release boom launch lock				
27.5	18.0	4.5	Deploy EEE boom (rest as required)		Payload Station: acknowledge boom deployment and monitor		Both rotary and push-pull arm motions used to deploy boom
29.5	2.0	4.6	Remove hand tool and tether to EEE structure				
31.0	1.5	4.7	Unstow and insert boom retention pin				Secures boom in extended position
36.0	5.0	4.8	Monitor sample cover activation and container rotation		Payload Station: activate experiment covers and rotate sample containers for checkout		Covers are removed only in the boom deployed position to avoid near-Orbiter contamination
38.5	2.5	4.9	Egress and remove EVA workstation; retrieve hand tool				
43.0	4.5	4.10	Translate to equipment stowage, ingress foot restraints and stow equipment	See Tasks 5.0 and 6.0			

TABLE 2.2.6: ATL Task Completion Plans -- Mission Scenario No. 2 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Deploy ATL (Mission 11) Pallet Mounted Experiment Subsystems

Sheet 7 of 10

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
44.5	1.5	4.11	Translate to task 7.0 work-site	↓			Task 7 is Lidar Measurement experiment
148.5	44.5						
			5.0 Remove and stow UV Meter Spectroscopy contamination cover and vent experiment container			NOTE: TASK 5.0 IS PERFORMED SIMULTANEOUSLY WITH TASK 4.0.	
	3.0	5.1	SEE TASK 4.0 (Tasks 5.0 and 6.0 are performed simultaneously with task 4.0)	Translate (with EV foot restraints) from equipment stowage to UV spectroscopy experiment			Refer to task sequence no. 3.11
	1.5	5.2	↓	Attach foot restraints at UV spectroscopy worksite		UV spectroscopy hardware	
	4.5	5.3	↓	Ingress restraints and inspect experiment			Confirm experiment external status
	4.5	5.4	↓	Vent contamination container	Payload Station: confirm contamination container totally depressurized		Precautionary measure only
	2.5	5.5	↓	Attach cover tether and release contamination cover retaining latches		UV spectroscopy contamination cover and latches	

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TABLE 2.2.6: ATL Task Completion Plans -- Mission Scenario No. 2 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Deploy ATL (Mission 11) Pallet Mounted Experiment Subsystems

Sheet 8 of 10

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
	2.5	5.6	See Task 4.0	Stow contamination cover in receptacle and lock			
	2.5	5.7		Inspect experiment for visual damage			
	1.0	5.8		Monitor during experiment activation	Payload Station: confirm experiment operational		
	1.0	5.9		Remove EV foot restraints and translate to Autonomous Navigation experiment			
	23.0						
		6.0	Remove and stow Autonomous Navigation contamination cover and release launch locks			NOTE: TASK 6.0 IS PERFORMED SIMULTANEOUSLY WITH TASK 4.0.	
	1.5	6.1	See Task 4.0	Attach foot restraints at Autonomous Navigation (AN) worksite			Refer to task sequence no. 3.11
	4.5	6.2		Ingress foot restraints and inspect experiment			
	2.5	6.3		Depress vent valve on contamination cover--bleed down if residual pressure	Payload Station: confirm contamination container totally depressurized	Autonomous Navigation experiment structure	Precautionary measure only

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TABLE 2.2.6: ATL Task Completion Plans -- Mission Scenario No. 2 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Deploy ATL (Mission 11) Pallet Mounted Experiment Subsystems

Sheet 9 of 10

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
	2.5	6.4	See Task 4.0	Attach cover tether and release contamination cover retaining latches		Contamination cover and latches	
	2.5	6.5		Stow contamination cover in receptacle and lock			
	2.5	6.6		Inspect experiment for visual damage			
	1.5	6.7		Release AN launch locks		Launch locks	Secure AN experiment hardware during launch and reentry
	2.5	6.8		Monitor during experiment activation	Payload Station: confirm experiment operational		
	1.5	6.9		Remove EV foot restraints and translate to Lidar Measurement experiment			
148.5	21.5						
		7.0	Remove and stow Lidar Measurement contamination cover and release launch locks				
1.5	1.5	7.1	Assist CM2 as required	Attach foot restraints at Lidar Measurement (LM) experiment		Lidar Measurement experiment structure	

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TABLE 2.2.6: ATL Task Completion Plans -- Mission Scenario No. 2 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Deploy ATL (Mission 11) Pallet Mounted Experiment Subsystems

Sheet 10 of 10

TIME (Min.)		SEQ.	FUNCTION AND CREW TASK			SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
CUM.	TASK		EVA CM1	EVA CM2	OTHER SUPPORT		
5.0	3.5	7.2	Inspect experiment exterior	Ingress foot restraints			
8.5	3.5	7.3	Same as above	Depress vent valve; bleed down if residual pressure	Payload Station: confirm contamination container totally depressurized		Precautionary measure only
10.5	2.0	7.4	Attach contamination cover tether	Release contamination cover retaining latches		Contamination cover	
13.0	2.5	7.5	Stow contamination cover in receptacle and lock	Inspect experiment for visual damage			
16.5	3.5	7.6	Release LM launch locks	Remove EV foot restraints and translate to equipment stowage		Launch locks	
18.5	2.0	7.7	Monitor during experiment activation	Ingress foot restraints and stow equipment		Equipment stowage locker	
20.0	1.5	7.8	Translate to equipment stowage	Close and latch stowage container			Configure equipment stowage container for reentry
25.0	5.0	7.9	Monitor Payload Station experiment status report; rest	Monitor Payload Station experiment status report; rest	Payload Station: confirm all experiments operational		
29.0	4.0	7.10	Translate to airlock and ingress	Translate to airlock and ingress		Handrails	EVA OPERATIONS COMPLETE
177.5	29.0						
TOTAL EVA TIME				TOTAL EVA TIME: 2 hrs., 58 min.			

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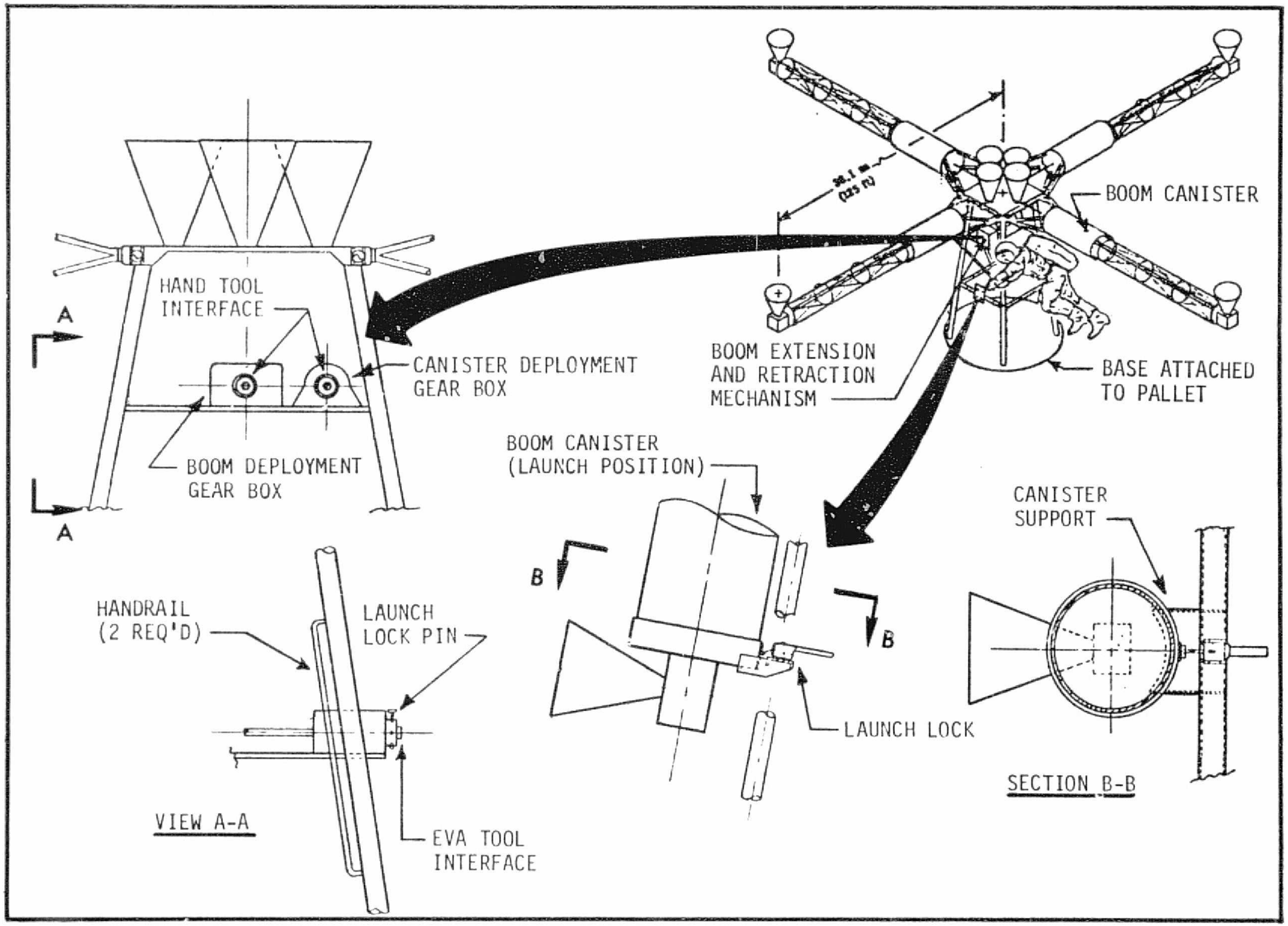


FIGURE 2.2-14: ATL Interferometer Experiment Manual Deployment Hardware Concepts/Interfaces

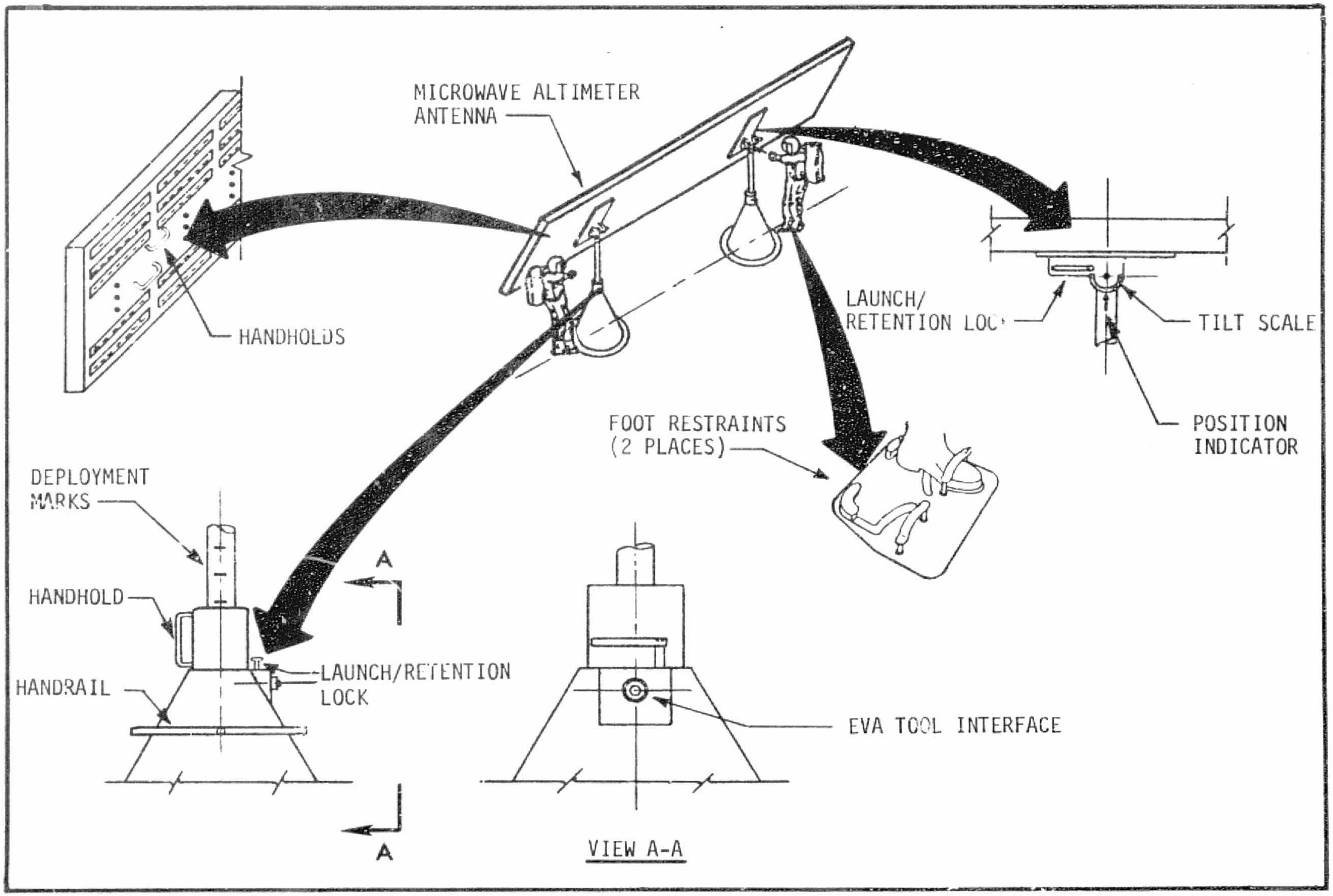


FIGURE 2.2-15: ATL Imaging Radar Experiment Manual Deployment Hardware Concepts/Interfaces

SPACE SHUTTLE EVA

- Sufficient experiment lighting is provided by the Orbiter to perform ATL EVA tasks.
- Portable foot restraints are provided for each EVA crewman.
- Tools are stowed in a locker attached to the experiment pallet.
- Two qualified crewmembers are available for conducting EVA. A third crewmember is available to perform minimal Payload Station experiment supporting functions and to monitor EVA operations (if required).
- Hardware concepts and crew interfaces were developed by the study contractor for procedures development only and are not intended to influence final component design.

SECTION 2.2 REFERENCES

2.2.1 NASA: Integrated Mission Planning, Spacelab No. 1 and Pallet Mission, Advanced Technology Laboratory, Marshall Space Flight Center, Book 11, Mission 11, September 19, 1974.

2.2.2 NASA: Study of Shuttle-Compatible Advanced Technology Laboratory (ATL), NASA TM-X-2813, Langley Research Center, September 1973.

2.2.3 NASA: Summarized NASA Payload Descriptions, Level A Data, SSPD Document (no reference numbers), Marshall Space Flight Center, July 1975 (Preliminary).

2.2.4 NASA: Payload Descriptions, Volume II, Sortie Payloads, Level B Data, SSPD Document (no reference numbers), Marshall Space Flight Center, July 1975 (Preliminary).

2.2.5 ESRO and NASA: Spacelab Payload Accommodation Handbook, ESTEC Reference No. SLP/2104, May 1975 (Preliminary).

2.3 LOW COST MODULAR SPACECRAFT

2.3.1 Introduction

The Low Cost Modular Spacecraft (LCMS) program provides the basis for a family of modular spacecraft satellites to be placed in orbits of various inclinations and altitudes. The low-cost standard hardware will comprise much of each satellite. Among other features, the design of the hardware will provide for on-orbit servicing by changeout of supporting subsystem assemblies. These system features, in association with Orbiter-based equipment and operational techniques, will permit on-orbit satellite maintenance and updating.

The satellites that result from the LCMS development will be used for various earth observations, including surveying and monitoring of terrestrial resources, identification and monitoring of surface and atmospheric pollutants, understanding of the physical behavior of the oceans and development of global weather forecasting and weather modification techniques.

A Special Note: During the development of the contract final report, the Low Cost Modular Spacecraft (LCMS) payload nomenclature was revised. In late 1975 the LCMS payload discipline terminology was changed to Multimission Modular Spacecraft (MMS). Therefore, the reader should make the correlation when reviewing this document.

2.3.2 Objective

The objective of the LCMS development is to produce a complement of standard subsystems capable of fulfilling common requirements of many missions. Each mission will naturally impose different requirements on the spacecraft which will be handled by a combination of mission unique hardware and software. The basic spacecraft structure and the Power,

Communications and Data Handling (C&DH) and Attitude Control System (ACS) modules, as shown by Figure 2.3-1, require no modification as the mission unique functions are added to the spacecraft.

2.3.3 Operational Modes

Three LCMS/Orbiter operational modes are planned, none of which include planned EVA.

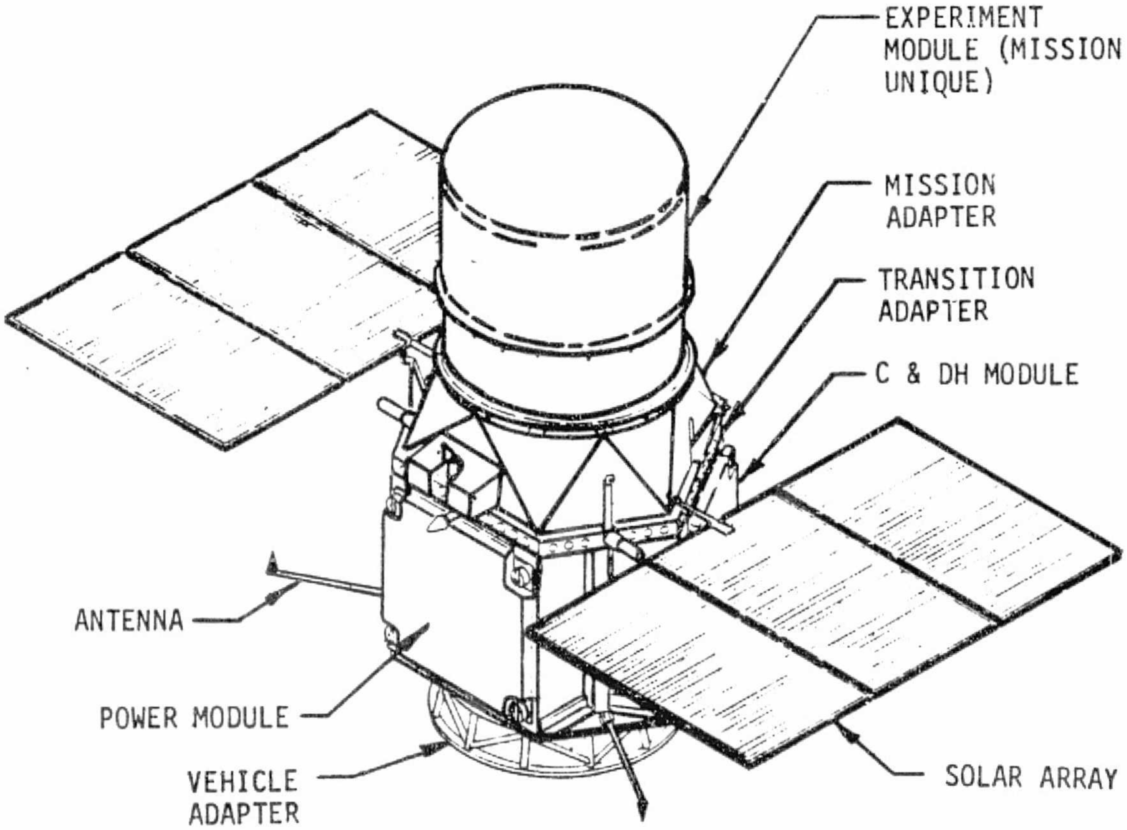


FIGURE 2.3-1: REPRESENTATIVE LCMS CONFIGURATION

The first mode of operation is Orbital Delivery, illustrated by Figure 2.3-2. The LCMS is carried into orbit in a retention cradle located in the Shuttle payload bay. After the payload bay doors have been opened, the LCMS is released from a retention cradle and erected for systems checkout. Deployment away from the Orbiter is accomplished by use of the RMS, after which the Orbiter maintains a stationkeeping attitude until satisfactory operation of the LCMS has been verified. To complete Mode 1 the Orbiter deorbits and lands while the LCMS is placed in an operational orbit. The major components of the LCMS, payload retention fixtures and module exchange equipment are described later in the document.

Mode 2 is Orbital Servicing, Figure 2.3-3. The Orbiter, carrying replacement modules and subsystems, rendezvous with the LCMS in a servicing orbit. After capture by the RMS, the LCMS is attached in a vertical position to a positioning platform in the payload bay for module replacement. A rotary module magazine (MM) located in the aft portion of the payload bay presents replacement modules at the proper time to a Module Exchange Mechanism (MEM). The exchange mechanism removes the old module from the LCMS and stows it temporarily, removes the new module from the magazine and installs it in the LCMS. The old module is then stowed in the module magazine. The remainder of Mode 2 is identical to Mode 1.

The third mode is Spacecraft Retrieval, Figure 2.3-4. The Orbiter, containing a retention cradle and positioning platform, completes a rendezvous with the LCMS and captures it with the RMS. The LCMS is then docked with the positioning platform, rotated into the payload bay and attached to the retention cradle. After payload bay door closure, the Shuttle deorbits and lands, thereby returning the LCMS for ground servicing.

2.3.4 Program Elements

As indicated by Figure 2.3-5, three distinct elements must work in consort to achieve mission goals. These elements are:

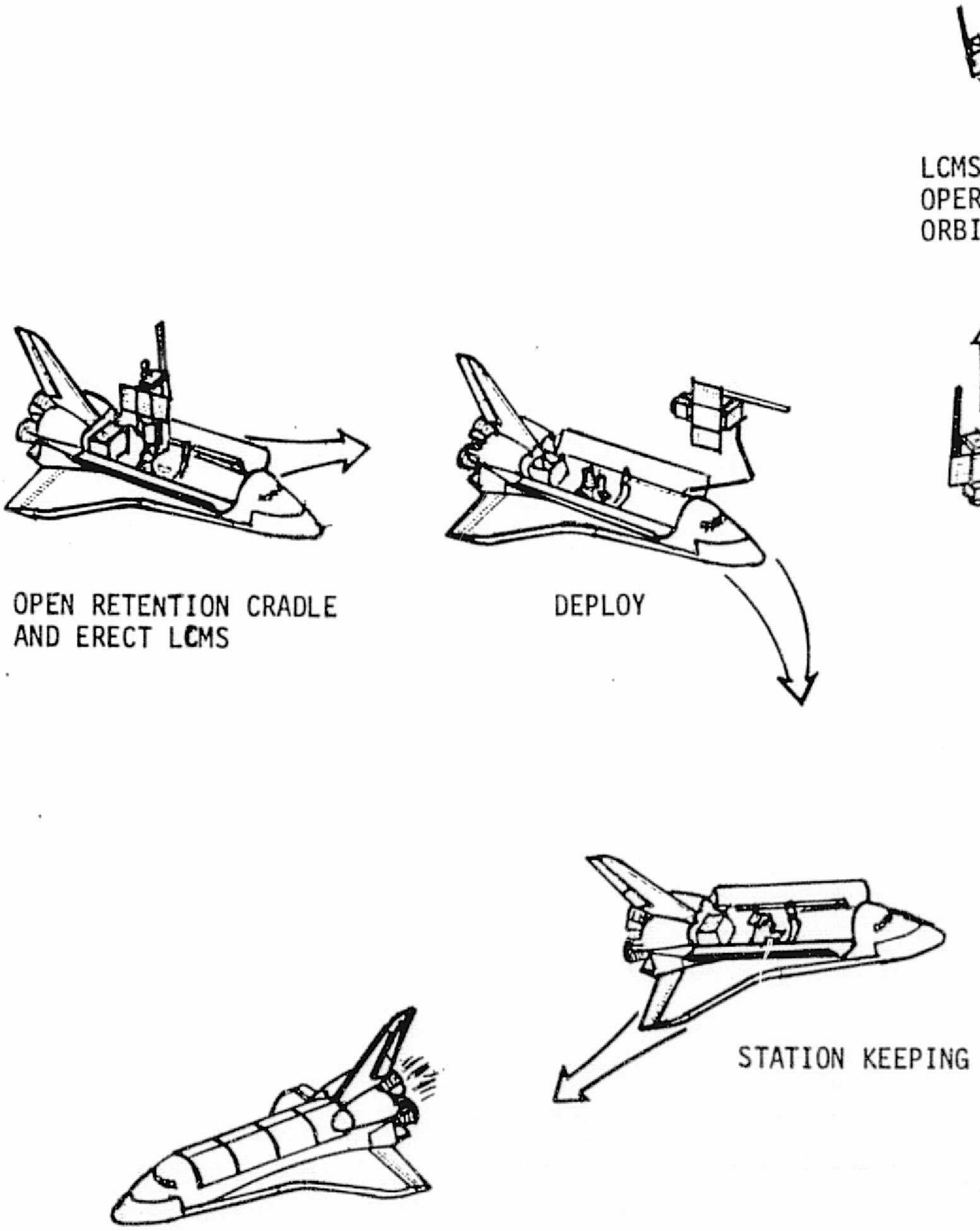


FIGURE 2.3-2: ORBITAL DELIVERY (MODE 1)

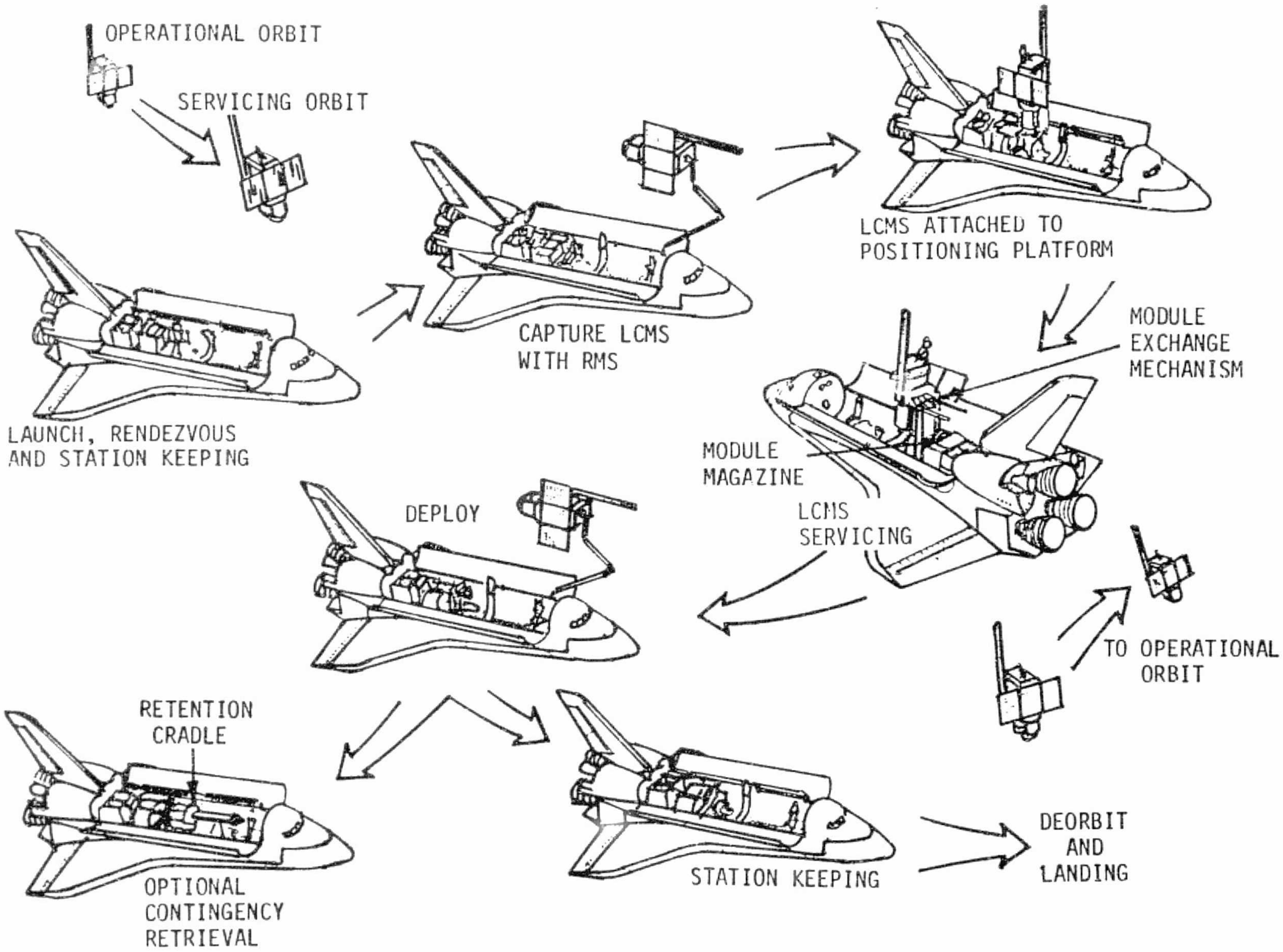


FIGURE 2.3-3: ORBITAL SERVICING (MODE 2)

SPACE SHUTTLE EVA

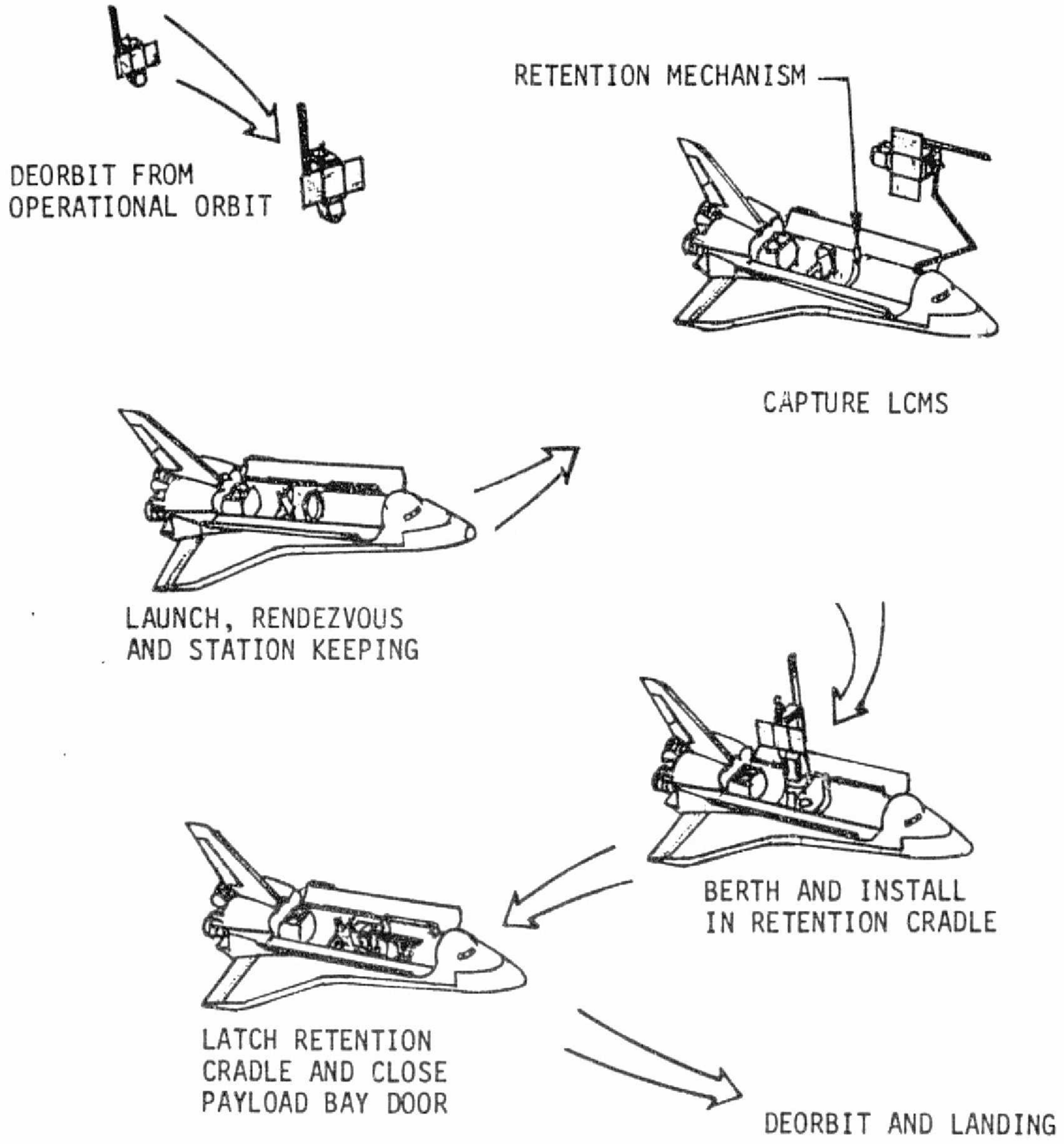


FIGURE 2.3-4: SPACECRAFT RETRIEVAL (MODE 3)

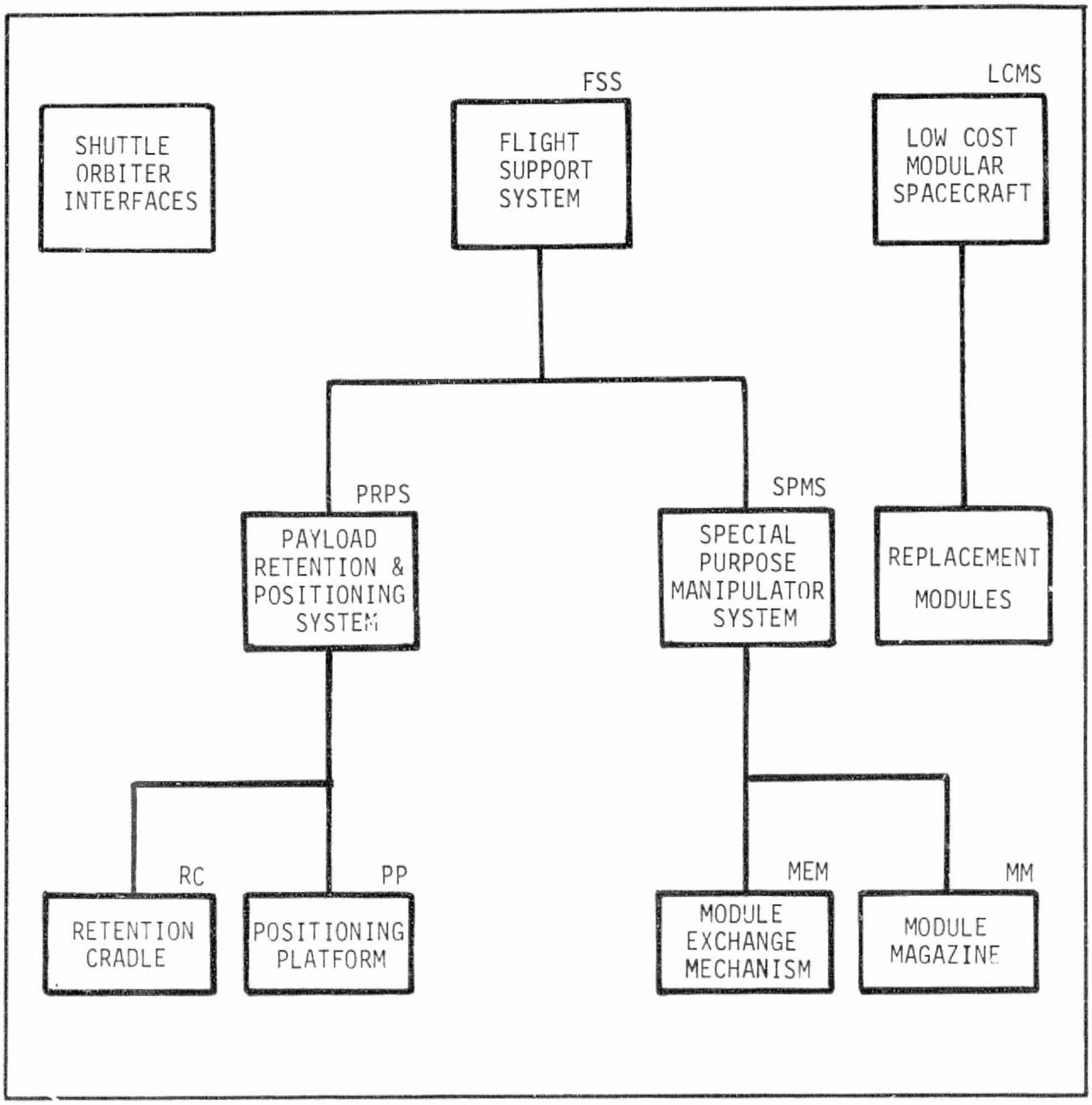


FIGURE 2.3-5: Program Elements

- Low Cost Modular Spacecraft (LCMS)
- Flight Support System (FSS)
- Orbiter Support Systems

2.3.4.1 Low Cost Modular Spacecraft

The baseline LCMS configuration contains three subsystem modules supported by a module support structure, which is common to a family of Earth Observatory Satellites (EOS). Mission unique features adapt the spacecraft to specific missions by adding special purpose subsystems. Some of the mission unique features are the solar arrays, solar array drive system, antennas, booms, experiment modules, propulsion modules and a mission adapter (Ref. Figure 2.3-6).

2.3.4.1.1 Subsystem Modules

The three subsystem modules (Attitude Control System Module, Power Module, and Communications and Data Handling Module) are physically the same size, Figure 2.3-7. All equipment is internally mounted on a baseplate that interfaces with the module radiator for heat rejection. Guides are provided on each side of the module to mate with the resupply rails on the module support structure for module replacement (Ref. Figure 2.3-6). The resupply latch mechanisms provide the necessary forces to engage or withdraw the attachment points and the electrical connectors associated with each module.

2.3.4.1.1.1 Attitude Control Subsystem Module - The purpose of the Attitude Control Subsystem is to orient and stabilize the spacecraft relative to a desired target. The basic ACS configuration is fixed for all mission types except geosynchronous orbits in which the magnetometer and magnetic torquers can be deleted. The balance of configuration options relates to reliability improvements through redundancy. The baseline ACS module has a total weight of 119.8 kg (264 lbs.) vs. 150.6 kg (332 lbs.) for the fully redundant configuration.

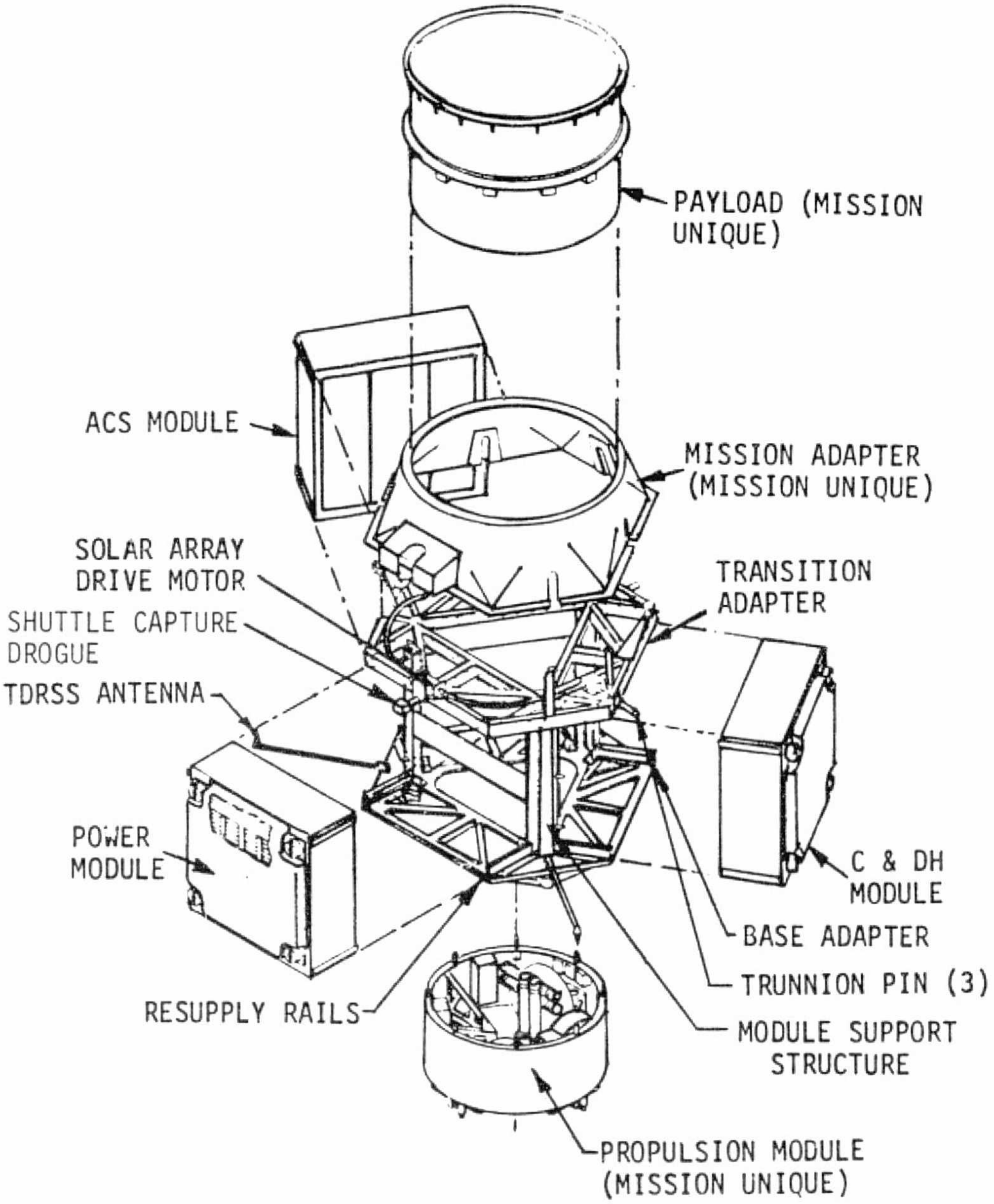


FIGURE 2.3-6: LOW COST MODULAR SPACECRAFT (EXPLODED VIEW)

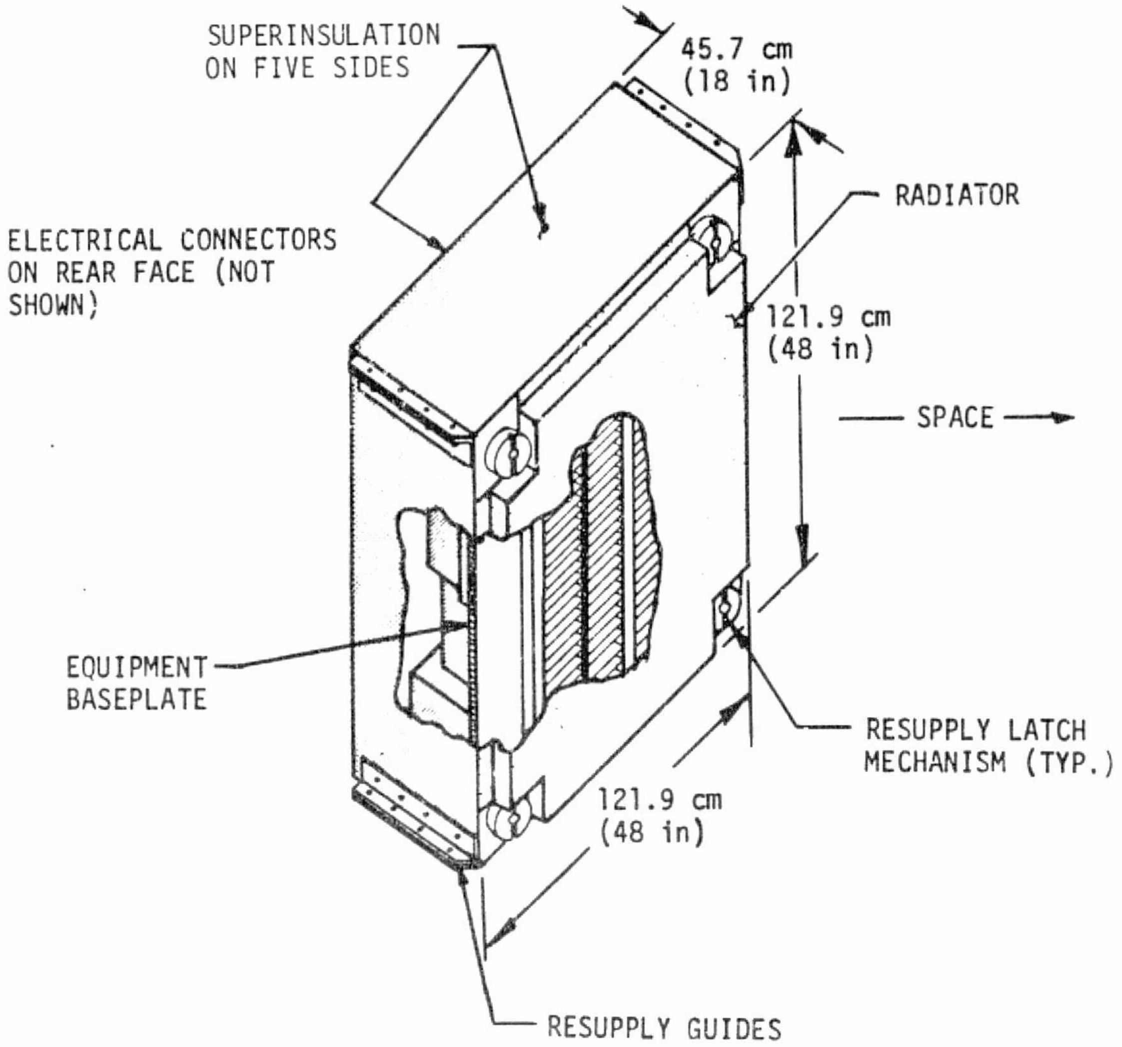


FIGURE 2.3-7: SUBSYSTEM MODULE

2.3.4.1.1.2 Communications and Data Handling Subsystem Module - The Communications and Data Handling Subsystem provides a means for ground and on-board control of all spacecraft and sensor functions and for retrieval of observatory data. This subsystem consists of the Communications equipment (RF transmitters and receivers) and data handling equipment (command group, telemetry group and an on-board computer). The baseline C & DH module weight i. 76.7 kg. (169 lbs). A fully redundant configuration is achieved by adding a second NSSC-1 computer for a total module weight of 90.3 kg. (199 lbs.).

2.3.4.1.1.3 Power Subsystem Module - The standardized power subsystem module is used in conjunction with mission unique solar arrays to accommodate a large number of missions at all orbit altitudes including geosynchronous. The module contains batteries, battery charger, decoders, multiplexers, a signal conditioner and ancillary equipment items. The baseline configuration, containing two 20 ampere-hour batteries, weighs 120.7 kg. (266 lbs.), while the fully redundant configurations contain three 50 ampere-hour batteries for a total weight of 236.8 kg. (522 lbs.).

2.3.4.1.2 Module Support Structure (MSS)

The module support structure is the basic structural component of the LCMS. Its purposes are to provide structural continuity when all modules are not in place, to provide a universal mounting bracket for electrical connectors and harnesses, to mount non-resuppliable hardware, and to interface with the subsystem module resupply latch mechanisms.

Key features of the module support structure are (Figure 2.3-8):

- Base adapter - contains lower subsystem module resupply rails and provides interface points for the FSS positioning platform.

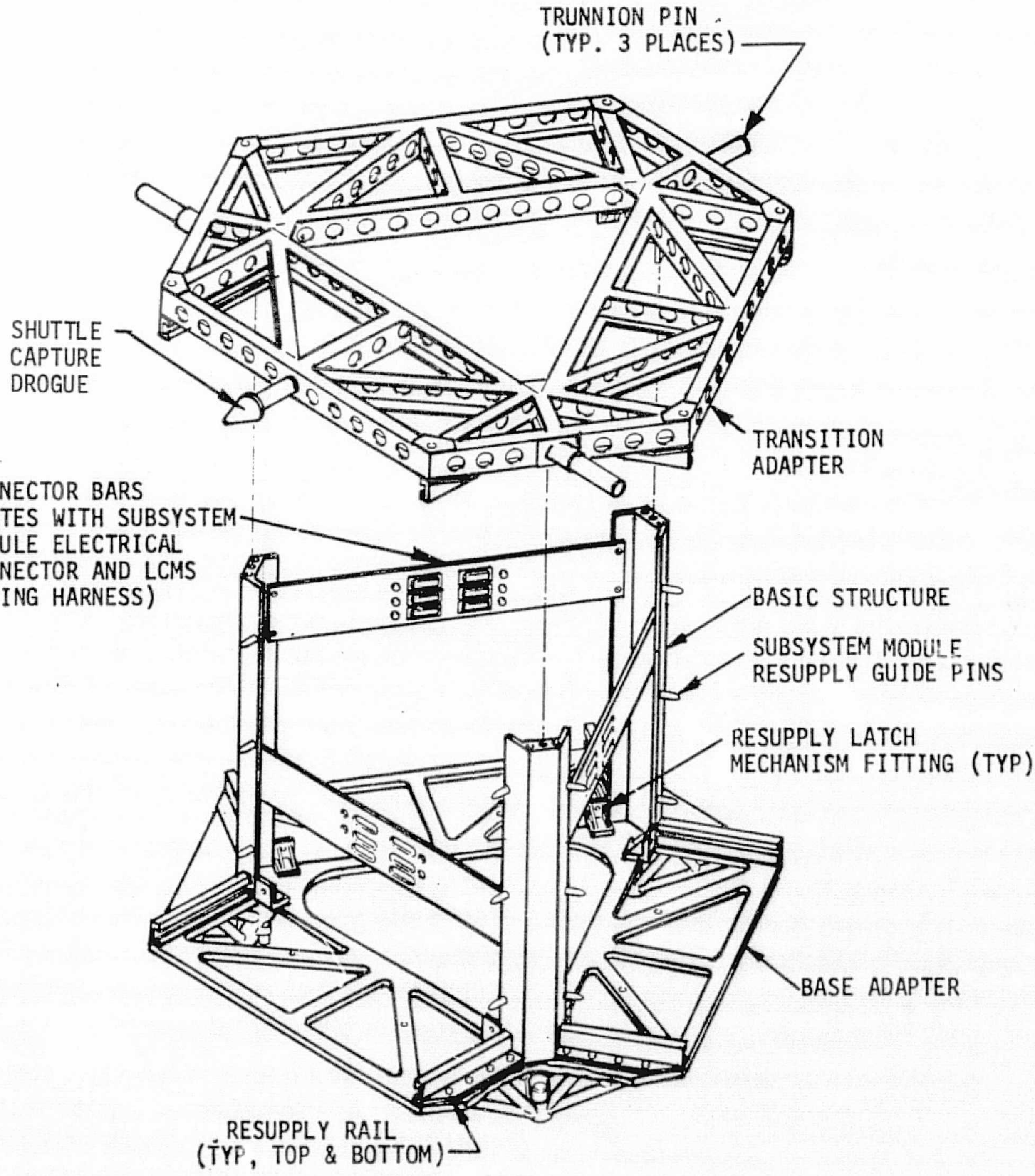


FIGURE 2.3-8: MODULE SUPPORT STRUCTURE

- Transition adapter - contains upper subsystem module resupply rails, the Shuttle capture drogue to interface with the RMS, three trunnion pins to interface with the FSS retention cradle and provide a base for attachment of experiment modules (payloads).
- Basic structure - contains subsystem module latch mechanism fittings, resupply guide pins and the connector bars for the resupply electrical connectors.

2.3.4.1.3 Propulsion/Actuation Module (PAM)

The propulsion/actuation module is a versatile unit that can be adapted to a wide range of spacecraft missions. It is defined as "mission unique" because most of the missions being considered for the modular spacecraft have different propulsion requirements. However, these requirements can be met by the four configurations shown in Figures 2.3-9 through 2.3-12.

Configuration I is the basic spacecraft propulsion system (i.e., SPS I) which provides only reaction control and orbit adjust. SPS I has a total impulse capability of 5.4×10^4 N-sec (12,000 lbf-sec).

Configuration II uses SPS I integrated with large reaction wheels and magnetic torquers to handle very large payloads.

Configuration III features a larger propulsion system using SPS II, which has a total impulse capability of 10.3×10^5 N-sec (230,000 lbf-sec) and can be used for orbit transfer, orbit adjust and reaction control.

In Configuration IV the large reaction wheels and magnetic torquers are integrated with an SPS II to provide maximum capability.

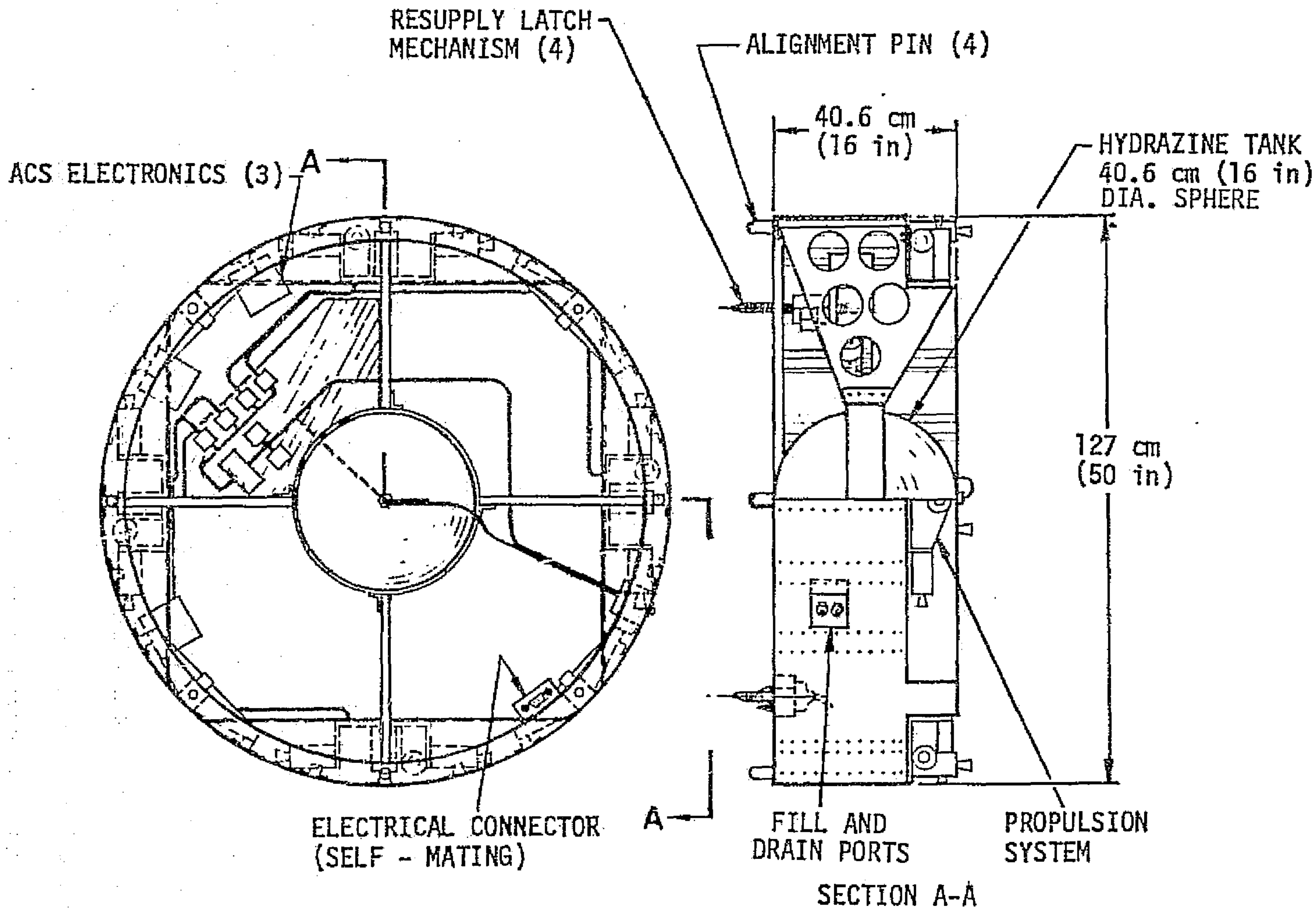


FIGURE 2.3-9: PROPULSION/ACTUATION MODULE-CONFIGURATION I WITH PROPULSION SYSTEM 1

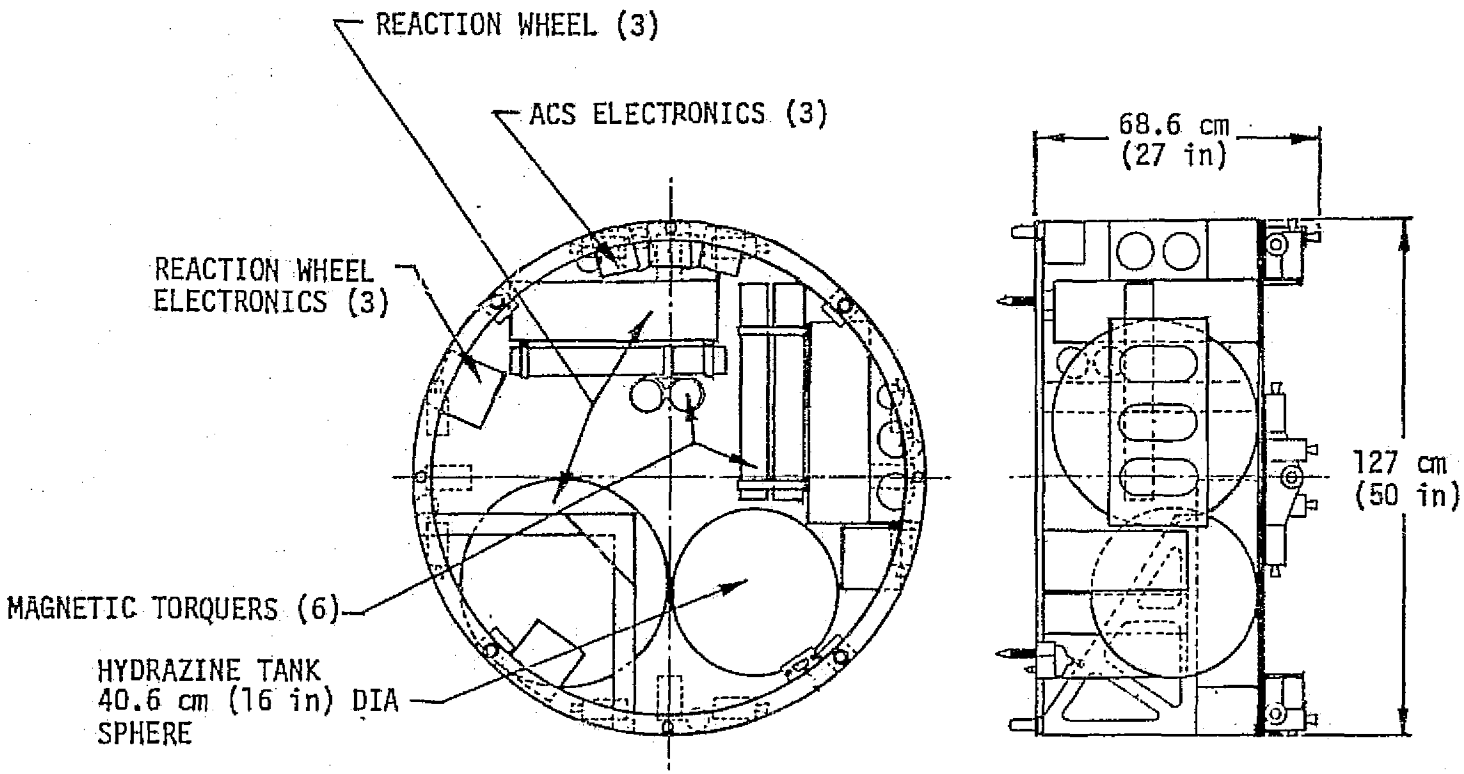


FIGURE 2.3-10: PROPULSION/ACTUATION MODULE-
CONFIGURATION II WITH PROPULSION
SYSTEM I AND AUGMENTED REACTION
CONTROL SYSTEM

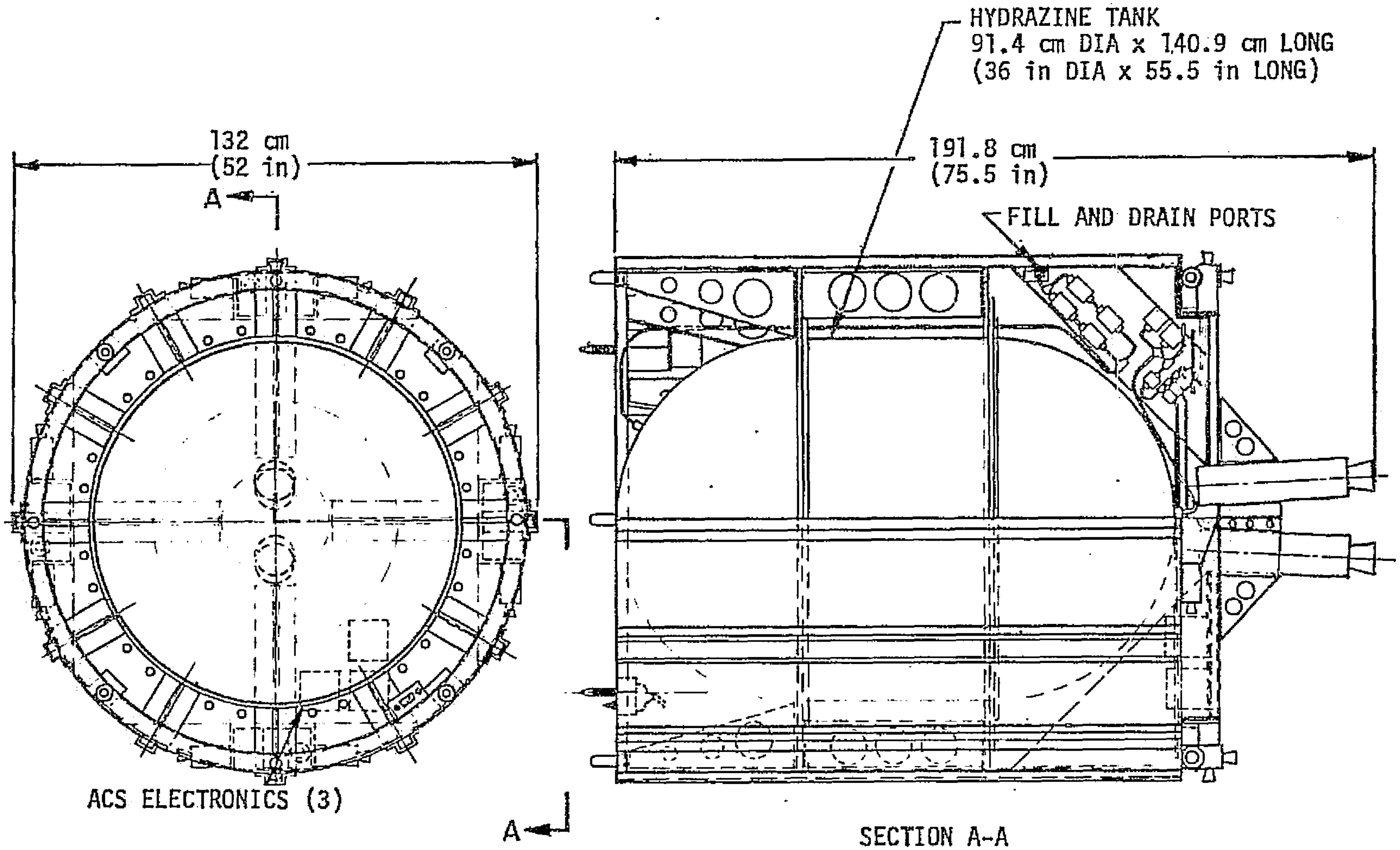


FIGURE 2.3-11 PROPULSION/ACTUATION MODULE-CONFIGURATION III WITH PROPULSION SYSTEM II

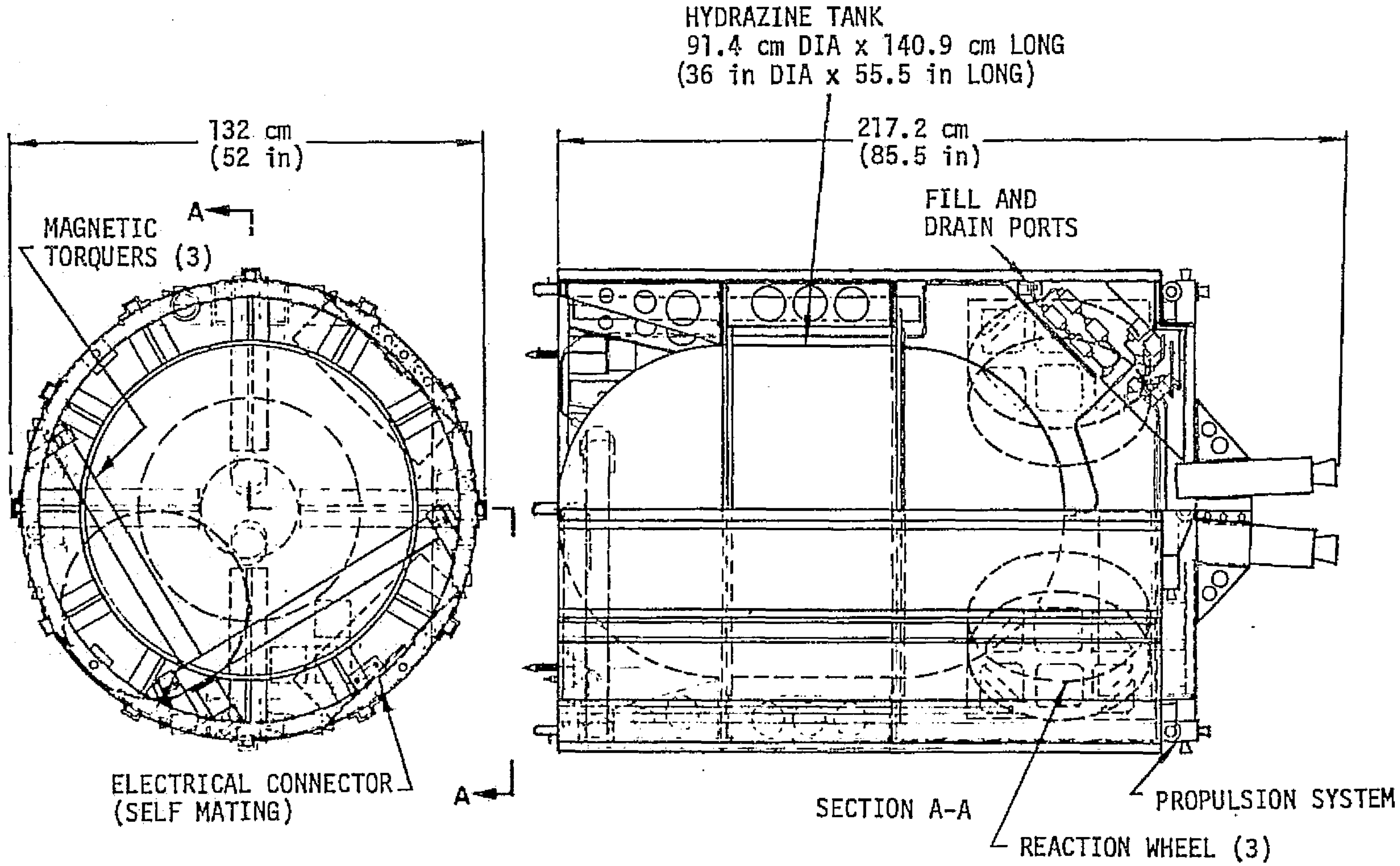


FIGURE 2.3-12: PROPULSION/ACTUATION MODULE-
CONFIGURATION IV, WITH PROPULSION
SYSTEM II AND AUGMENTED REACTION
CONTROL SYSTEM

All of the configurations may be attached to the lower portion of the module support structure. Configuration I is compatible with the Delta launch vehicle adapter. It will fit inside the empty volume of the lower portion of the module support structure and the launch vehicle adapter, Figure 2.3-13. Configurations II, III, and IV are Shuttle Orbiter configurations and are not restrained by a Delta launch vehicle adapter. Although they have the same basic LCMS attach points, their lengths and diameters are not restricted. All of the configurations, however, are reserviceable since they are self-contained, and the only interfaces are rudimentary electrical and mechanical connections.

2.3.4.1.4 Mission Unique Features

The objective of this modular spacecraft development is to produce a complement of standard subsystems capable of fulfilling common requirements of many missions. Each mission will naturally impose different requirements on the spacecraft which will be handled with a combination of mission unique hardware and software. It is important to note that the module support structure and the Power, C & DH, and ACS subsystem modules require no modification as mission unique functions are added to the spacecraft.

The mission unique features include a varity of solar arrays, antennas, experiment modules and adapters and propulsion modules.

2.3.4.2 Flight Support System

The Flight Support System (FSS) consists of the payload retention and positioning system (PRPS) and the special purpose manipulator system (SPMS) located as shown in Figure 2.3-14. Each item of FSS equipment is mission peculiar and is ground installed as required to support the LCMS mission. For example, only the PRPS would be required for an LCMS delivery mission; while a refurbishment mission would require both the PRPS and the SPMS.

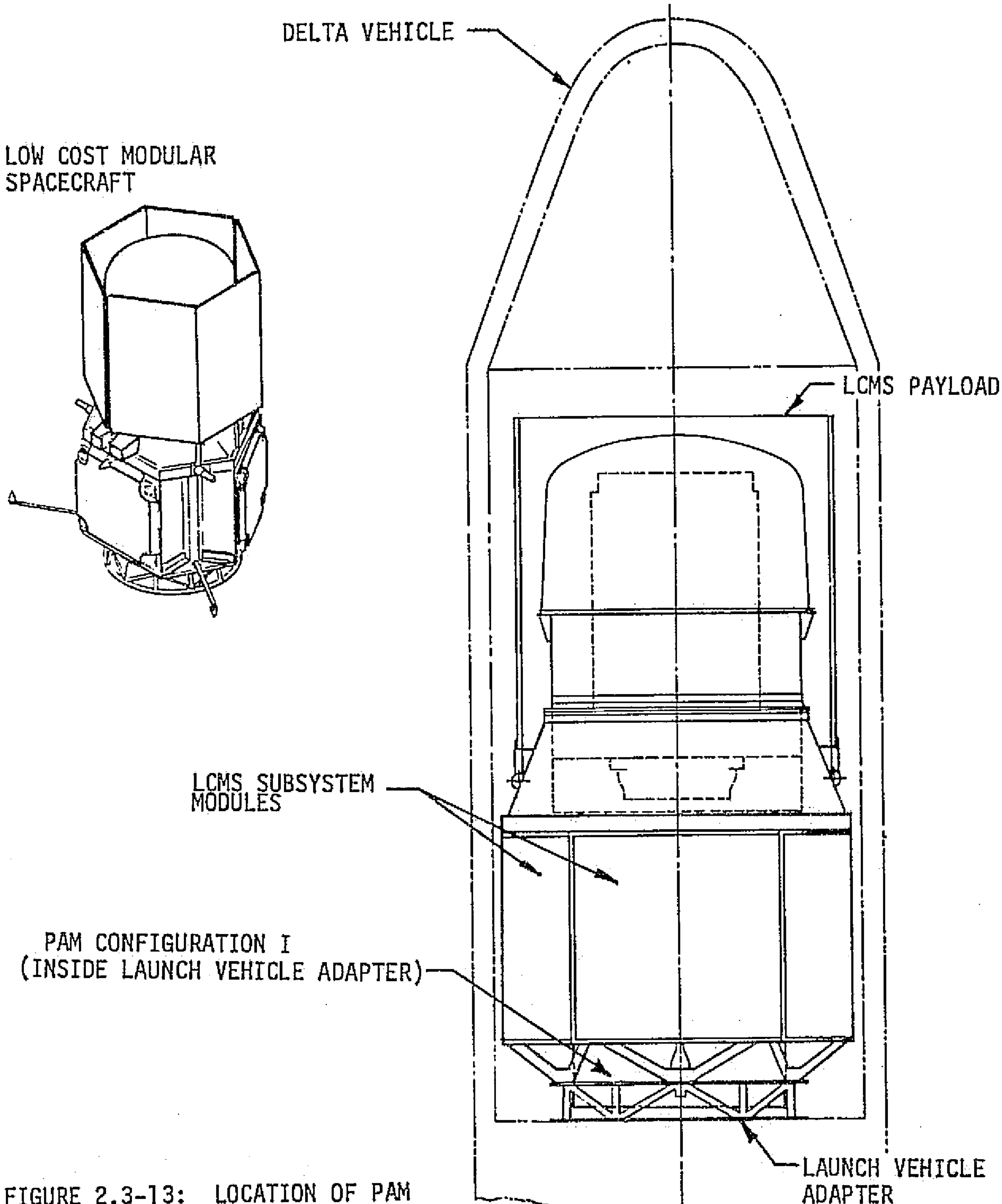


FIGURE 2.3-13: LOCATION OF PAM CONFIGURATION I FOR DELTA LAUNCH

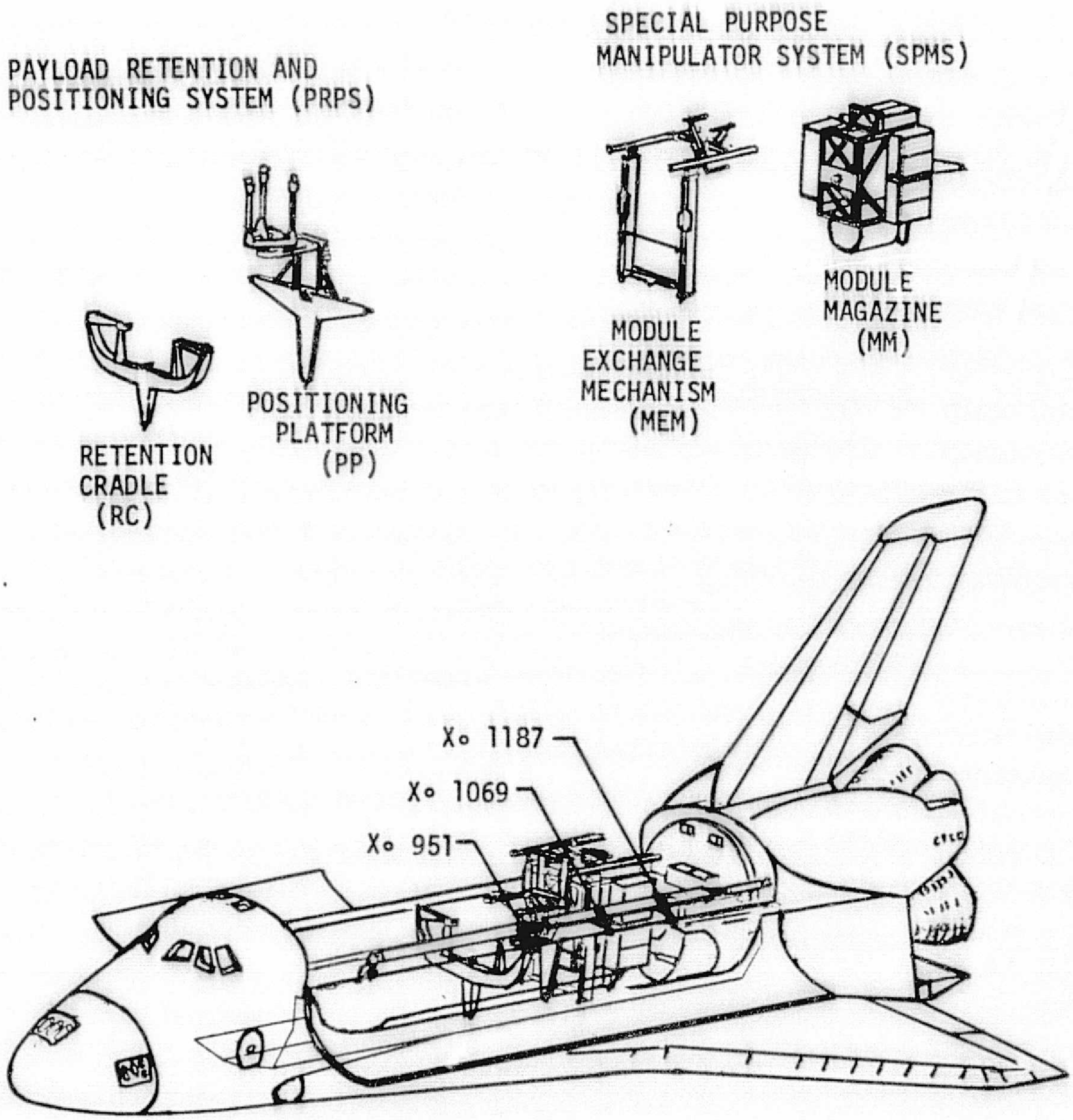


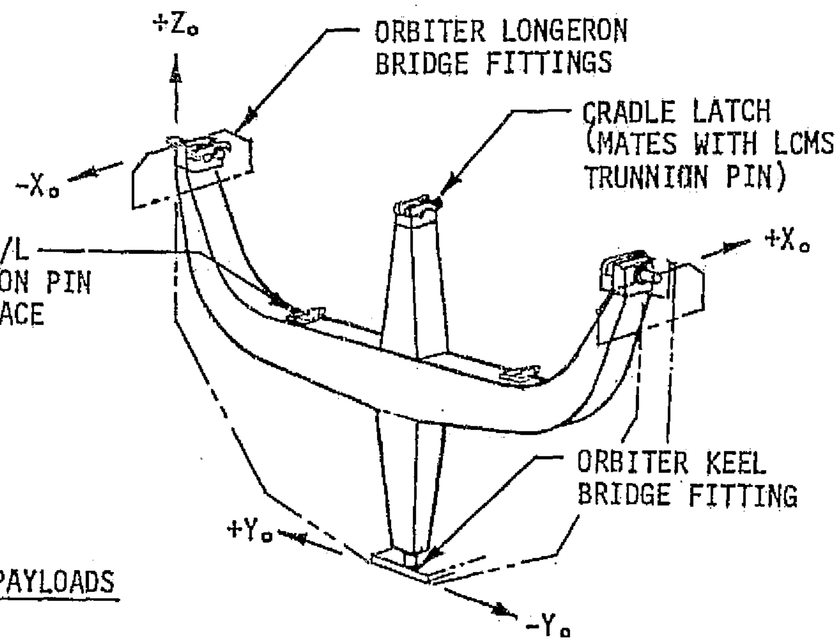
FIGURE 2.3-14: FLIGHT SUPPORT SYSTEM

2.3.4.2.1 Payload Retention and Positioning System

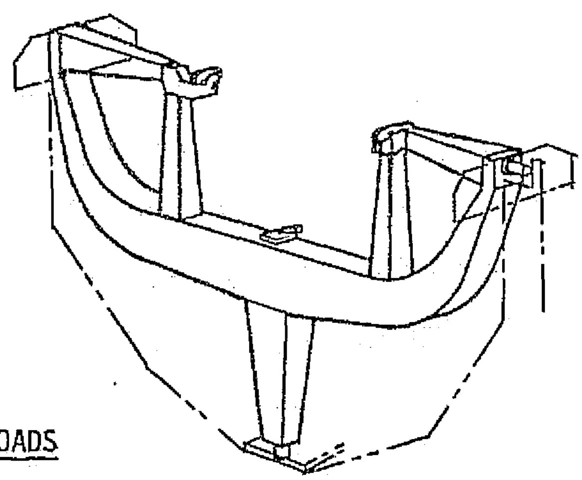
The PRPS includes two major structural items: (1) retention cradle and (2) positioning platform, plus the support subsystem identified in Figure 2.3-5.

- Retention Cradle. In order to provide the structural support of the LCMS in the Orbiter cargo bay, a structural bridge between the Orbiter structure and the transition adapter on the module support structure of the LCMS is required. This function is provided by standard Orbiter fittings supporting a retention cradle structure which latches in turn to trunnions on the transition adapter. Figure 2.3-15 illustrates two concepts for the retention cradle. One has the capability to hold two LCMS in a side-by-side arrangement thus permitting a dual launch or retrieval with a minimum demand for cargo bay length. The bay could thus be utilized for other payloads which would share the transportation costs. The other cradle has the capacity to carry a single LCMS. For both the dual and single installation the LCMS is held by two electrically actuated latches, similar to the Orbiter standard latch, which react the loads in the X- and Z-axes. A pin on the lower center-line of each LCMS transition adapter reacts X- and Y- axial loads into a receptacle in the cradle.

  Horizontal and vertical loads are transmitted to the Orbiter longeron bridge fittings for reaction by the two attachment fittings on the sides of the cradle structure. Horizontal and lateral loads are transmitted to the Orbiter keel bridge fitting for reaction by an attachment fitting on the bottom of the cradle structure.



DUAL PAYLOADS



SINGLE PAYLOADS

FIGURE 2.3-15: PAYLOAD RETENTION CRADLE CONCEPTS

- Positioning Platform. The Positioning Platform (PP), Figure 2.3-16, provides a number of functions for the operations of the FSS as follows:

  - The docking mechanisms provide the hard dock with the LCMS required to retain and position the LCMS while it is extended from the payload bay. Payload checkout can be accomplished while the LCMS is attached to the PP after extension from the cargo bay.

  - The extend and retract movement and the rotation of the LCMS about its longitudinal axis to permit access for the remove and replace operations are provided by the 90-degree lift and the rotation mechanisms.

  - After stowage of the LCMS in the retention cradle, it is necessary to retract the docking latches to decouple the load path between the LCMS and the PP to ensure that all loads are carried through the cradle.

  - The forward end of the module magazine is supported by the lateral member of the PP support structure.

  - The vertical support members of the module exchange mechanism are supported at three attachment points on the PP support structure.

  - The RMS operator will have the option of selecting any two docking mechanisms for intital contact and then rotating the LCMS to seat the third probe.

2.3.4.2.2 Special Purpose Manipulator System

The Special Purpose Manipulator System (SPMS) is part of the Orbiter Flight Support System (FSS) for the in-orbit operations of refurbishment

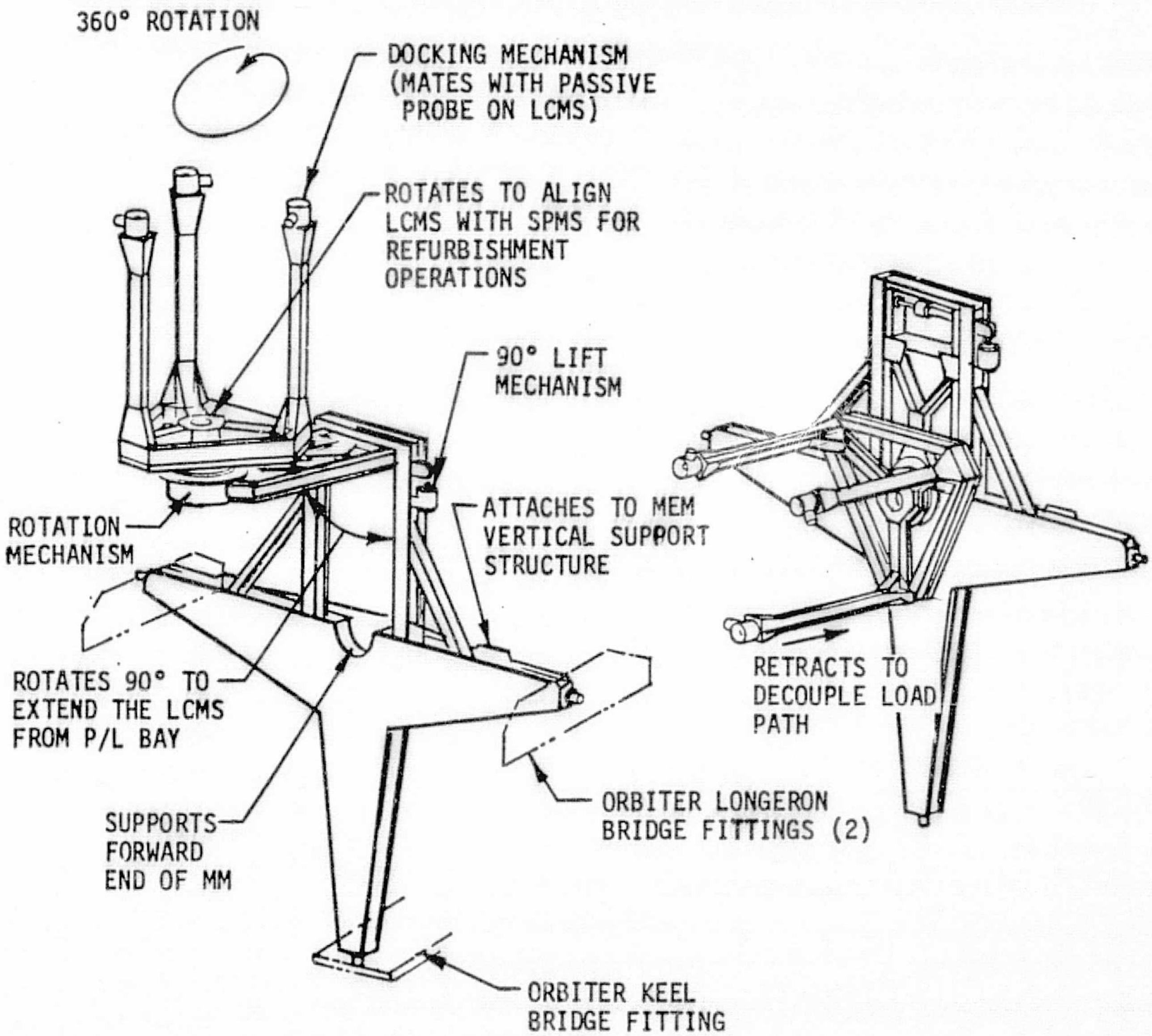


FIGURE 2.3-16: POSITIONING PLATFORM CONCEPT

and resupply of the LCMS family of satellites. The SPMS flight configuration is shown in Figure 2.3-17 supported by the positioning platform as it would be installed in the Orbiter payload bay.

The basic functions of the SPMS (once the LCMS has been docked to the Orbiter and prepared for refurbishment) consist of:

- Indexing the module storage magazine to the appropriate orientation.
- Unlatching and removing the replacement modules from the magazine.
- Unlatching and removing the used modules from the satellite.
- Interchanging the new and used modules and placing them in the satellite and storage magazine.
- Locking the modules into their respective locations.
- Returning to its stowage position in the orbiter bay.

The SPMS includes: (1) Module Exchange Mechanism (MEM) and (2) Module Magazine (MM).

- Module Exchange Mechanism. The MEM transports the new and used modules (subsystems) between the module magazine and the LCMS location and operates the resupply latch mechanism that secures the modules to LCMS or MM structure, Figure 2.3-18.

  The MEM is a four degree-of-freedom manipulator system with three translational degrees of freedom in the orthogonal (X, Y, Z) coordinate system of the Orbiter vehicle. The fourth degree-of-freedom (DOF) is rotation about the Y-axis in the common plane of symmetry of the Orbiter, MM, MEM and the LCMS. The fourth DOF allows the interchange of locations of the new and used modules during the module exchange sequence and allows for minor angular adjustments in the most critical (X, Z)

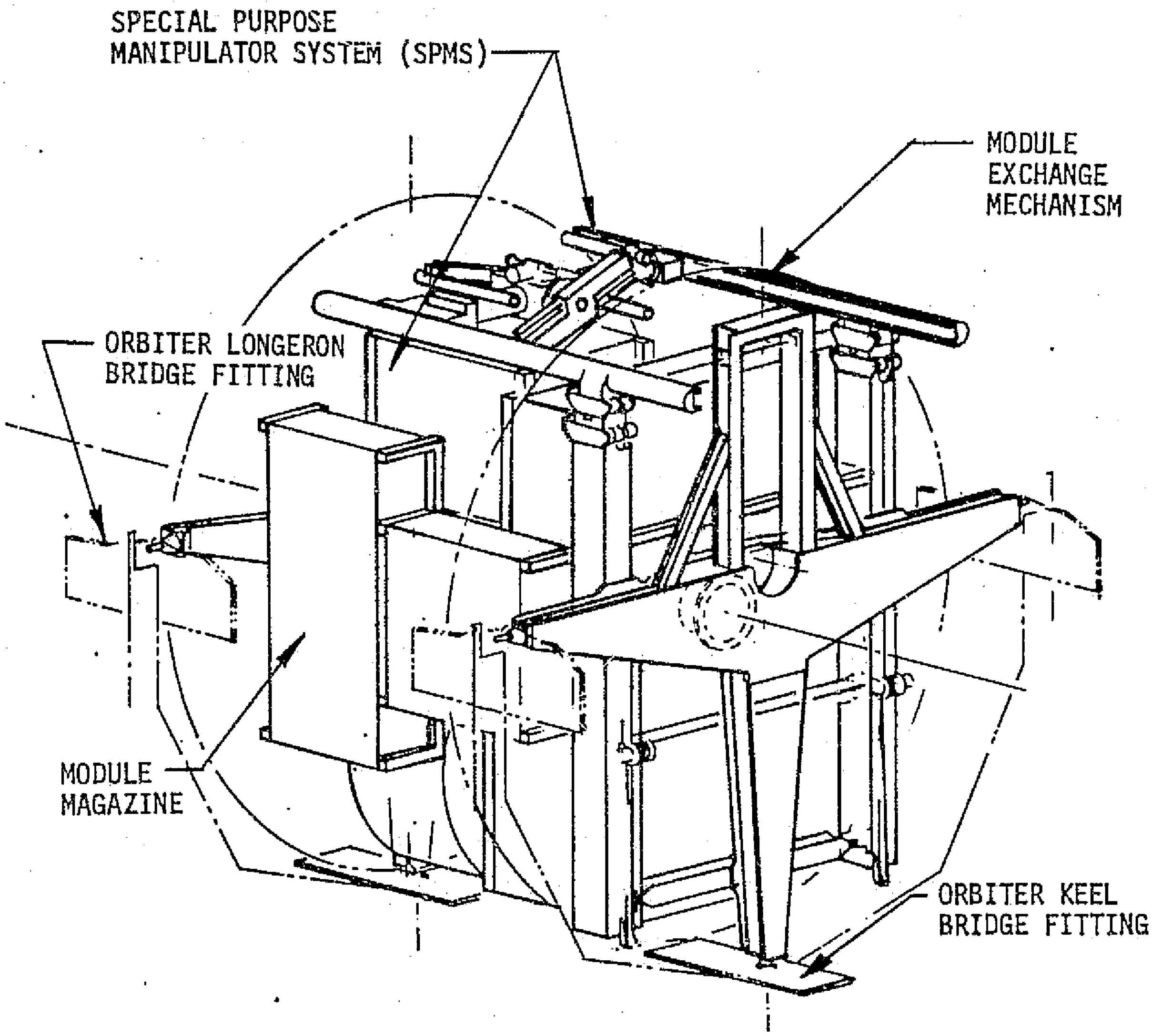


FIGURE 2.3-17: SPECIAL PURPOSE MANIPULATOR SYSTEM CONFIGURATION

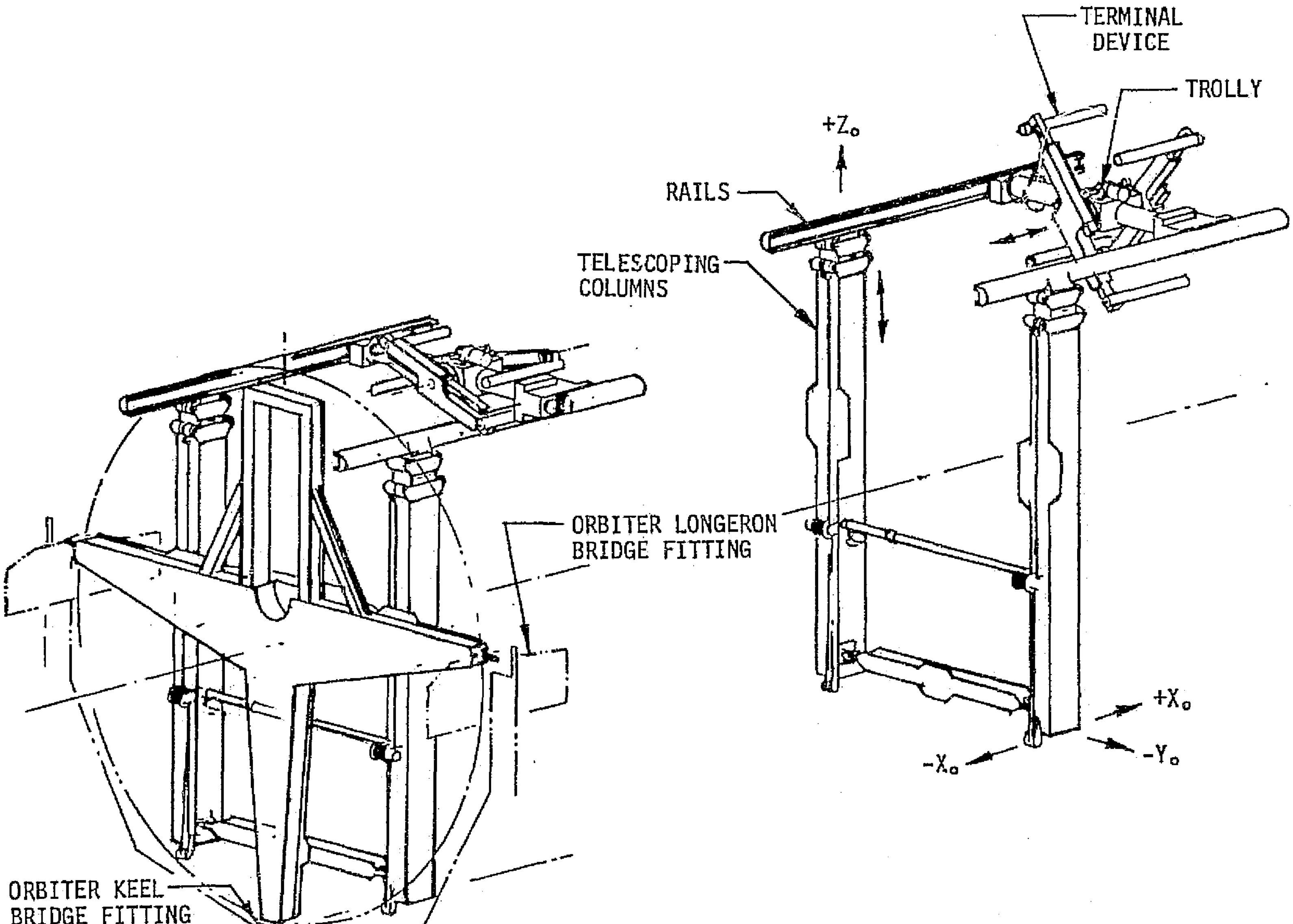


FIGURE 2.3-18: MODULE EXCHANGE MECHANISM

direction during module insertion.

The MEM consists of:

- Two vertical telescoping columns which move the modules parallel to the LCMS axis once it has been attached to the PP.
- Two fixed length rails mounted on top of the columns.
- A trolley that moves along the rails carrying the terminal device.
- A double-sided terminal device that attaches to and transports the modules.

- Module Magazine. The MM provides storage of re-supply modules for the LCMS. The MM must accommodate a wide range of subsystem, propulsion/actuation, and experiment modules, since the module contingent will vary for each mission. The MM and the MEM are positioned within the space between the PP and the OMS kit and must provide access to each of the modules. Module access is provided by rotating the MM, Figure 2.3-19.

In order to determine which LCMS refurbishment tasks can be accomplished by EVA, it is necessary to define the requirements placed on the SPMS for task accomplishment, then compare those specifications with the EVA capabilities found in Volume I, Section 3. Table 2.3.1 defines the SPMS specifications.

2.3.4.3 Orbiter Support Systems

2.3.4.3.1 Cargo Bay Interfaces

Flight Support System (FSS) Installation in Cargo Bay. The baseline stations for the FSS components are as follows (Ref. Figure 2.3-14):

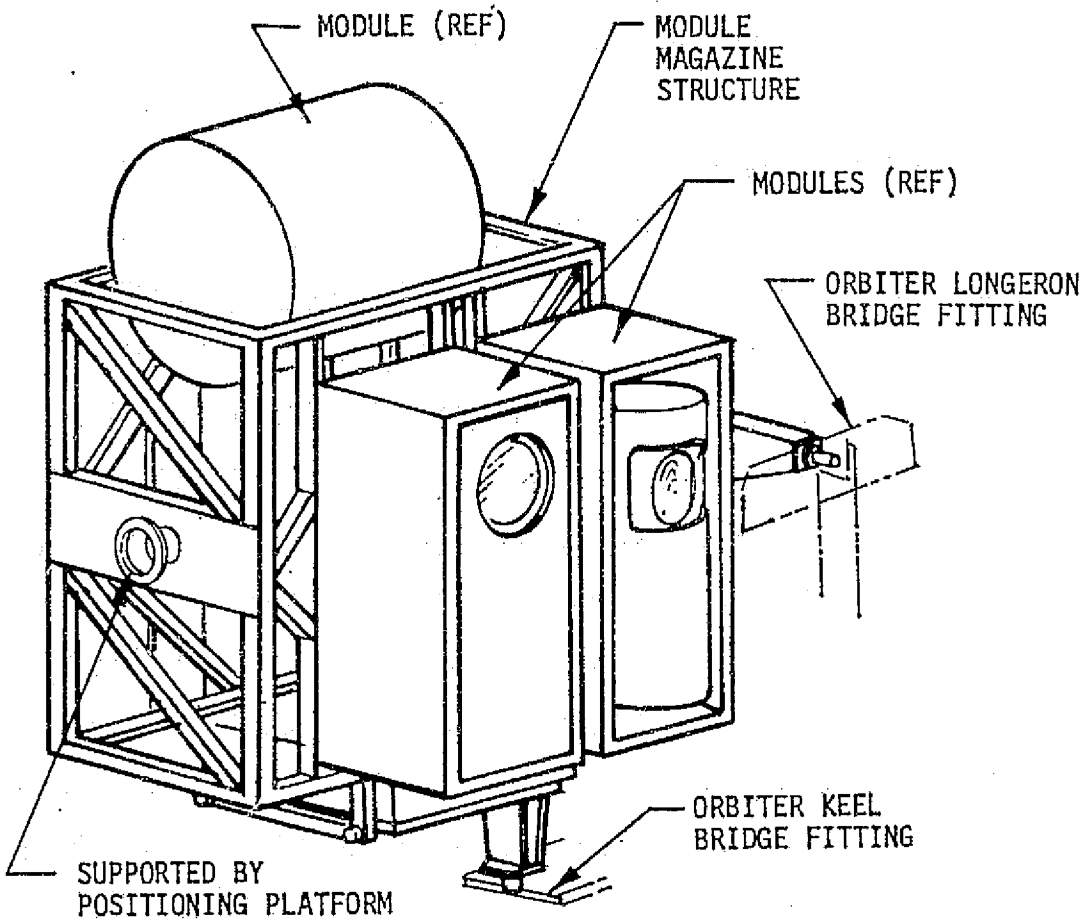


FIGURE 2.3-19: MODULE MAGAZINE

TABLE 2.3.1: SPM System Specification

1.	Classification	High force, high precision orthogonal axis module exchange system, man-in-the-loop
2.	Working stroke	3.30 m (130 in.) in X-axis
		5.44 m (214 in.) in Z-axis
		1.02 m (40 in.) in Y-axis
3.	Tip force	136 kg (300 lb) through .46 m (18 in.) travel
4.	Stiffness of structure	41 kg/cm (230 lb/in.) (at full extension)
5.	Precision (no load)	±0.64 cm (±0.25 in.)
6.	Speed of operation	2.54 cm/sec (1 in./sec) (unloaded)
		0.25 cm/sec (0.10 in./sec) module engage under 136 kg (300 lb) load
7.	Stopping distance	0.64 cm (0.25 in.) at 2.54 cm/sec (1 in./sec) with 408 kg (900 lb) mass
8.	Dexterity and control	4 DOF, force feedback control, visual position sensing
9.	Storage capacity	Up to 9 subsystem and experiment modules
10.	Weight	1288 kg (2840 lb)
11.	Operational power	250 watts
12.	Cycle time	15 minutes nominal
13.	Flight environments	Shuttle launch and orbit

SPACE SHUTTLE EVA

Center Line of Support Structure	X_o Orbiter Station
Retention Cradle	951
Positioning Platform	1069
Module Magazine aft support	1187

2.3.4.3.2 Pressurized Compartment Interfaces

Control Panel Envelope: The man-machine interface for those operations associated with deployment, retrieval, and refurbishment of the LCMS is performed using control panels located in the pressurized compartment. Presently these control panels are located in the Payload Station (PS) in the aft portion of the flight deck with the majority of the space on the minus Y side of the cabin as shown in Figure 2.3-20.

The PS will have the standard provisions for an Orbiter avionics keyboard and Cathode Ray Tube (CRT) from which pages of command/control data stored in the computer can be displayed.

Control System Definition: The control system provides the interface between the operator and the module exchange mechanism and can vary from a fully automated system, in which only the modules to be exchanged are selected, to a manual control system in which the operator directly controls every step of the exchange sequence.

2.3.4.3.3 Ancillary Orbiter Support

The LCMS/FSS concept is one where the command and control of the LCMS/FSS is accomplished from dedicated control panels at the PS and from the ground. As such the Orbiter primary function is to provide the launch platform and the environment from which necessary orbit operations can be performed. These include the necessary mechanical support, the electrical power for deployment/refurbishment, the wiring between the cargo bay bulkhead to the patch panel in the pressurized compartment, the space for mounting dedicated equipment, etc. The support which the Orbiter can provide in the areas of data processing, external communications,

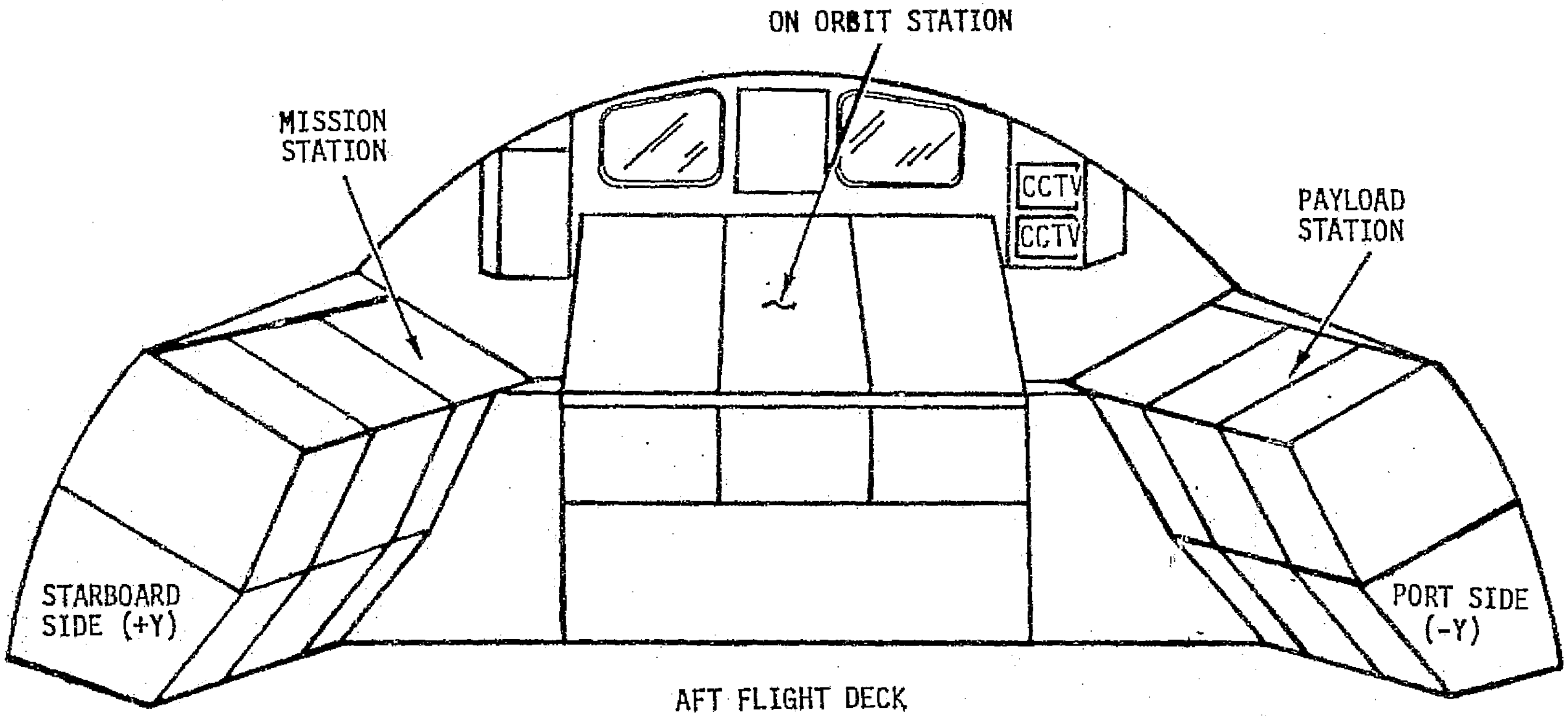


FIGURE 2.3-20: PAYLOAD STATION

tracking, display, television, etc. is defined as ancillary support. The capabilities which the Orbiter is providing in these areas are described as follows:

- Command, Control and Data Interfaces: The Orbiter provides major ancillary support in the command, control, and data for payloads which are attached or detached.

- Communications: The communications support the Orbiter can provide the LCMS includes the functions of data transfer, tracking, voice communications, EVA communications (if required), and television.

- Electrical Power: The Orbiter will provide 50 kwhr of electrical energy for payload usage. With the addition of mission kits, chargeable to the payload, additional cryogenics can be provided to allow an additional 840 kwhr of energy.

2.3.5 LCMS EVA Task Description

2.3.5.1 Planned EVA

All required tasks for deployment, retrieval, inspection and repair of the LCMS are currently planned to be accomplished through use of the FSS, RMS, and TV systems. Therefore, EVA is not a planned activity for the LCMS program.

2.3.5.2 Unscheduled and Contingency EVA

Unscheduled or contingency EVA is recognized as a viable approach to solving problems associated with the LCMS and its interfacing equipment and systems. An analysis of the Low Cost Modular Spacecraft reveals a number of situations where damage to or malfunction of automatically actuated systems could limit mission success, and in certain cases cause loss of vehicle and necessitate crew rescue. A malfunction in the docking release mechanism and rotation mechanism leaves the LCMS extended from the payload bay and attached to the positioning platform. A malfunction of the module exchange mechanism while inserting or removing a module from the LCMS or the module magazine would prevent payload bay door closure. A variety of minor problems, each capable of being solved via EVA, could limit refurbishment mission success. Table 2.3.2 lists potential unscheduled and contingency EVA tasks.

2.3.5.3 Potential Planned EVA

Potential planned EVA may be defined as candidate EV operations that could be performed if the man-machine interfaces were designed for on-orbit EVA servicing and operations. The replacement of subsystem modules, erection and deployment of antennas and solar arrays, and stowage/retrieval of replacement modules should be considered as prime EVA tasks, thereby allowing a reduction in FSS cost, weight and complexity. Table 2.3.2 lists potential planned EVA tasks.

TABLE 2.3.2: LCMS EVA Task Identification

UNSCHEDULED EVA	CONTINGENCY EVA	POTENTIAL PLANNED EVA
<u>LCMS</u> • Release and deploy antenna • Fold and stow antenna • Release and deploy solar arrays • Fold and stow solar arrays • Unjam deployment mechanisms • Release trunnion pins from RC cradle latches • Inspect for potential servicing and repair • Retrieve unstable LCMS • Deploy LCMS (using RMS) • Free jammed RMS end effector • Remove debris • Connect/disconnect electrical cable(s) • Free jammed attachment fittings	<u>LCMS</u> • Release and jettison solar array • Disengage and stow antenna • Unjam replacement module blocking MM or MEM and jettison • Deploy LCMS (using RMS) • Jettison LCMS • Disconnect electrical cables • Disengage damaged LCMS from RMS and stow/jettison <u>FLIGHT SUPPORT SYSTEM</u> • Work station deployment, use and stowage	<u>LCMS</u> • Unstow, attach and erect solar arrays • Detach and stow solar arrays • Remove and replace subsystem modules • Remove and replace propulsion module • Remove and replace experiment modules • Retrieve/deploy LCMS (using RMS) <u>FLIGHT SUPPORT SYSTEM</u> • Connect/disconnect power umbilicals • Unstow/stow, erect and use portable work stations • Dock LCMS to fixed positioning platform in P/L bay.

TABLE 2.3.2: LCMS EVA Task Identification (continued)

UNSCHEDULED EVA	CONTINGENCY EVA	POTENTIAL PLANNED EVA
• Portable light placement	• Rotate PP into P/L bay	• Eliminate the MM, using pallet storage instead
• Camera placement	• Release and jettison PP	• Unstow, transfer and install new modules on LCMS
• Monitor operations	• Retract and stow MEM	• Transfer and stow spent modules on pallet
• Override module resupply latch mechanism	• Release and jettison MEM	• Eliminate MEM, using the RMS with EVA assist instead
FLIGHT SUPPORT SYSTEM	• Release partially inserted module from LCMS to allow MEM stowage	
• Mate/release LCMS docking probe with PP docking mechanism	• Release partially inserted module from MM and stow or jettison	
• Rotate LCMS/PP from/into P/L bay	• Release and jettison MM	
• Rotate PP to position module for SPMS/LCMS refurbishment operation	• Disentangle RMS from damaged LCMS and stow	
• Unjam MEM and stow	• Jettison entangled RMS and LCMS	
• Realign modules and MEM		
• Unjam module from MM		
• Manually rotate MM for module access		

2.3.5.4 Task Definition

Analysis of the LCMS payload resulted in the identification of representative tasks within the capabilities of the EVA crewman and support system technology. The tasks listed in Table 2.3.2 are typical of the twelve classifications described in Table 2.2.1 and require specific sub-tasks for completion. The tasks are intended to illustrate a significant range of EVA capabilities available to the payload community and not a critical design review of the payload or associated support systems. EVA task outlines are developed in the following subsections to define major task requirements, sub-task classification, and ancillary information. Typical EVA tasks are selected to develop representative EVA mission scenarios. Preliminary procedures and timelines are developed for each scenario in subsequent sections of this report.

2.3.6 LCMS EVA Mission Scenarios, Timelines and Procedures

Since no planned LCMS EVA operations are currently identified, three hypothetical EVA missions are defined by selecting tasks from Table 2.3.2 and combining the tasks to develop typical payload servicing missions. LCMS EVA Mission Scenario's No. 1 and 2 assume credible malfunctions or anomalies resulting in inoperative payload systems, flight support systems equipment, or Orbiter support equipment, including failures in more than one area. LCMS EVA Mission Scenario No. 3 represents payload operations in which the EVA mission replaces several of the currently baselined automated functions. Payload modification and deletion of automated subsystems would be required, Further study is recommended to introduce a manual LCMS payload servicing method, via EVA, with emphasis on reduction in payload development, launch and servicing costs.

2.3.6.1 LCMS EVA Mission Scenario No. 1 - Deploy Payload

LCMS EVA Mission Scenario No. 1 is based on a selection of unscheduled EVA tasks from Table 2.3.2. This hypothetical EVA mission assumes malfunction of flight support system components and associated Orbiter equipment items that prevent payload deployment by the primary method. Two EVA crew members are required to perform the necessary operations to effect payload deployment. The deployment operations include:

1) Portable light placement
2) Inspect and diagnose
3) LCMS release (from retention cradle)
4) Deploy LCMS (using RMS), with EVA visual direction of deployment task
5) Solar array deploy - manual
6) Free jammed RMS end effector
7) Complete LCMS deployment.

The major tasks involved and task performance rationale are contained in Table 2.3.3.

TABLE 2.3.3: LCMS EVA Tasks--Mission Scenario No. 1

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
DEPLOY PAYLOAD	Perform a two-man "unscheduled" EVA to deploy the LCMS and its subsystems to complete the Shuttle mission	FSS power loss, debris jam, and actuation mechanism malfunction necessitate EVA for mission completion
1. PORTABLE LIGHT PLACEMENT		
• Egress airlock and translate to tool stowage	Crew translation using handrails along payload bay	Requires crew mobility aids to tool stowage. RC heater power must be "OFF"
• Unstow tool kit and portable lights	Retrieve tools and support equipment	Standard Orbiter tools required
• Transfer equipment to worksite	Hand carry equipment to worksite	Equipment tethered to translating crewman
• Install portable lights	Attach, connect and activate lights	Required to illuminate latch release area
2. INSPECT/DIAGNOSE		
• Inspect RC/LCMS interface	Inspect trunnion pin/RC latch assembly for damage, debris or misalignment	Crew tether point required
• Monitor LCMS release attempt	Cycle latch mechanism via switch on Panel A7 as a trouble-shooting technique	Tethered EVA crewmen to monitor unlatching attempt

TABLE 2.3.3: LCMS EVA Tasks--Mission Scenario No. 1 (continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
• Diagnose problem	Determine cause of malfunction and repair method	EVA crewman identifies specific tool requirements and defines plan
3. LCMS RELEASE		
• Remove tools from tool kit	Unstow tools and attach tethers	Tools required: Loop pin removal tool, adjustable wrench, hammer and pry bar
• Disconnect and release RC latches from LCMS trunnion pins	Remove latch hinge bolt pin, remove nut, drive bolt from hinge, pry hinge away from trunnion pin and stow all loose parts	One each, port and starboard sides
4. DEPLOY LCMS		
• RMS deploy	Remove from RC and deploy approx. 7.6m (25 ft) from Orbiter	Operated from Orbiter payload station
• EVA visual direction and operations monitor	Verify actual removal from RC at trunnion pin/latch interface	EVA crewmen remain in P/L bay
5. SOLAR ARRAY DEPLOYMENT		
• Direct RMS positioning of LCMS	Identify proper positioning of LCMS for manual release of solar array	LCMS to be in proximity of P/L bay, in a vertical position

TABLE 2.3.3: LCMS EVA Tasks--Mission Scenario No. 1 (continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
• Don and check-out MMU's	Each EV crewman must translate to the MMU station, don and check-out MMU and prepare for EVA outside the P/L bay	MMU's required for translation to and from worksite outside P/L bay
• Translate to worksite and attach tethers	Hand carry tools to worksite, attach tethers and prepare for array release	Tools required are: Metal shears, pry bar and 3/8" drive socket set
• Release array restraint mechanism	Remove cover bolts, shear portion blocking release pin, pry pin free	Release mechanism must be free to allow array to deploy
• Monitor deployment operation	Release tethers, translate to P/L bay floor and monitor deployment	EVA crewmen to remain in general proximity until deployment has been achieved
6. FREE JAMMED RMS END EFFECTOR		
• Translate to RMS end effector area	Translate to LCMS. Attach tethers. Survey end effector problem and identify repair plan	MMU required for translation to worksite
• Cut/pry material from end effector attachment	Debris must be trimmed and removed to permit end effector release	Tools required are: Shears and pry bar
• Translate to trunnion pin area of transition adapter	Stabilize LCMS and monitor end effector release. Assist as required	RMS to be stowed after end effector release

TABLE 2.3.3: LCMS EVA Tasks--Mission Scenario No. 1 (continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
7. LCMS DEPLOYMENT		
• Move LCMS to approx. 7.6 m (25 ft) from Orbiter, position and release	Two EVA crewmen to translate with LCMS to release site, properly orient the payload and release it in a stable condition	After tether release, EVA crewmen to perform fly around inspection of LCMS and return to Orbiter
• Transfer tools and portable lights to stowage area and stow	Return tools to tool kit. Detach and disconnect portable light. Return all equipment to stowed position	First crewman to stow tools, second crewman the portable lights
• Translate to MMU stowage area and stow MMU's	Return MMU's to stowage area, doff, stow and recharge, if required	Requires both EV crewmen
• Translate to airlock and ingress		TASK COMPLETE

2.3.6.2 LCMS EVA Task Completion Plans - Mission Scenario No. 1

The LCMS EVA task completion plans provide a preliminary set of procedures and timelines to demonstrate that the selected EVA payload tasks can be accomplished by application of the Shuttle EVA system. The task completion plans delineate major elements of the EVA mission and the extravehicular mission support requirements including number of crewmen, EVA mission time, translation aids and location, restraints, tools and crew safety concerns.

Preliminary timelines and procedures developed for mission scenario no. 1 are provided in Table 2.3.4. Assumptions associated with the mission scenario include the following:

- Sufficient mobility aids (handholds, handrails) are provided by the payload and/or Shuttle Orbiter to access the LCMS/PP from the airlock.
- Realizing the possible requirement for an unscheduled EVA, crew mobility aids are provided by the payload for access to each LCMS associated area.
- Since design details were not available for many of the LCMS subsystems, conceptual designs were developed by the contractor to implement procedures development.
- Two qualified crewmembers are available for conducting EVA. A third crewmember is available to perform minimal Payload Station (PS) EV supporting functions.

The LCMS mission scenario no. 1 is predicated on the necessity to override non-operating automated systems to release, activate and deploy the LCMS. The EVA begins as an unaided EVA, as shown in Figure 2.3-21, and is completed via EVA with the MMU. EVA operations are depicted in Figures 2.3-22 through 2.3-24.

TABLE 2.3.4: LCMS EVA TASK COMPLETION PLANS-MISSION SCENARIO NO.1

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: DEPLOY PAYLOAD MODE: UNAIDED EVA and EVA WITH MMU Sheet 1 of 6

TIME (Min.)		SEQ.	FUNCTION AND CREW TASK			SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
CUM.	TASK		EVA CM1	EVA CM2	OTHER SUPPORT		
		1.0	Prepare for unscheduled two-man EVA for manual release of LCMS, beginning with portable light placement.				
4.5	4.5	1.1	Egress airlock and translate to tool stowage area	Egress airlock and translate to tool stowage area		P/L bay handrails	
8.5	4.0	1.2	Unstow portable lights	Unstow tool kit			
11.0	2.5	1.3	Transfer portable lights to worksite	Transfer tool kit to worksite and tether for temporary storage.		P/L bay handrails	
19.0	8.0	1.4	Install, connect and adjust light at port trunnion fitting	Install, connect and adjust light at starboard trunnion fitting		LCMS/RC fittings	*Portable lights (2)
19.0	19.0						
		2.0	Inspect LCMS/RC interface area, monitor actuation attempts and define work plan				
23.0	4.0	2.1	Inspect LCMS/RC interface area	Assist CM1: Inspection of LCMS/RC interface area			Look for obvious damage or fitting misalignment/binding

*EVA support equipment required to complete LCMS Mission Scenario No. 1 to be provided by payload.

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TABLE 2.3.4: LCMS EVA TASK COMPLETION PLANS-MISSION SCENARIO NO. 1 (Continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: DEPLOY PAYLOAD

Sheet 2 of 6

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
35.0	12.0	2.2	Monitor port latch actuation attempts. Determine status	Monitor starboard latch actuation attempts. Determine status	Payload station: Actuate RC latch switch, cycle 6 times	RC latch switch is located on Panel A7	
37.5	2.5	2.3	Diagnose problem and devise work plan	Assist CM1			
37.5	18.5						
		3.0	Remove RC latches and release LCMS for deployment				
52.5	15.0	3.1	Observe RMS operation	Observe RMS operation	Payload Station: Attach RMS end effector to LCMS capture drogue to retain payload when latches are released	RMS end effector to capture drogue; operated from Payload Station.	SAFETY NOTE: Crewmen stand clear and observe RMS operation
57.5	5.0	3.2	Attach tool tethers and prepare for RC latch removal	Unstow tools and pass to CM1. Deploy carry-all container on tether		EMU tether	Tools required are: *loop pin removal tool, adjustable wrench, hammer and pry bar
77.5	20.0	3.3	Remove port latch bolt loop pin, remove nut, drive bolt from hinge joint and pry latch cap away from trunnion pin	Assist CM1. Capture and stow loose parts			Body tethers required for stabilization at work-site. EVA work station may also be required

*EVA item required to complete LCMS Mission Scenario No. 1 to be provided by payload.

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TABLE 2.3.4: LCMS EVA TASK COMPLETION PLANS-MISSION SCENARIO NO.1 (Continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: DEPLOY PAYLOAD

Sheet 3 of 6

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
97.5	20.0	3.4	Repeat for starboard latch assembly	Assist CM1			SEE FIGURE 2.3-21
97.5	60.0						
		4.0	Deploy LCMS using RMS				
109.5	12.0	4.1	Monitor release of LCMS trunnion pin from port RC latch and payload deployment	Monitor release of LCMS trunnion pin from starboard RC latch and payload deployment	Payload Station: Operate RMS to remove LCMS from RC and deploy	RMS attached to Shuttle capture drogue on LCMS transition adapter	CM1 and/or CM2 may be required to pry trunnion pin free of latch if mis-alignment causes binding
109.5	12.0						
		5.0	Attempt solar array deployment, don MMU's and release solar array				
124.5	15.0	5.1	Direct positioning of LCMS for array deploy-ment	Monitor operation -- discuss manual deployment approach	Payload Station: Position LCMS and actuate deployment switch	EMU tether	Failure to deploy requires CM1 and CM2 to don MMU's and release solar arrays
154.5	30.0	5.2	Translate to MMU station and don/checkout MMU. Stow tools for transfer to work site	Translate to MMU station and don/checkout MMU. Stow carry-all con-tainer for transfer to worksite	Payload station: Maintain RMS/LCMS position. Deactivate deployment switch	MMU station	

TABLE 2.3.4: LCMS EVA TASK COMPLETION PLANS-MISSION SCENARIO NO.1 (Continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: DEPLOY PAYLOAD

Sheet 4 of 6

TIME (Min.) CUM.	TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	EVA CM2	OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
158.5	4.0	5.3	Translate to worksite and attach tethers. Unstow tools	Translate to worksite and attach tethers. Unstow carry-all container			SEE FIGURE 2.3-22
176.5	18.0	5.4	Remove cover bolts and cover. Using shears, cut sheet metal jamming mechanism	Stow bolts and cover in container. Pry debris from mechanism		EMU tether	Tools required are: 3/8" drive socket set, pinch bar and metal shears
180.0	3.5	5.5	Monitor deployment	Monitor deployment	Payload Station: Actuate deployment switch		
183.5	3.5	5.6	Stow tools, release tethers and return to P/L bay	Stow carry-all container, release tethers and return to P/L bay			
183.5	74.0						
		6.0	Remove Debris and Free Jammed RMS End Effector				
191.0	7.5	6.1	Translate to RMS/LCMS interface, diagnose problem and unstow tools	Translate to RMS/LCMS interface and assist in developing work plan	Payload Station: Attempt to release LCMS		End effector does not release payload.* Tools required are: shears and pinch bar

*EVA support equipment required to complete LCMS Mission Scenario No. 1 to be provided by payload.

TABLE 2.3.4: LCMS EVA TASK COMPLETION PLANS-MISSION SCENARIO NO.1 (Continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: DEPLOY PAYLOAD

Sheet 5 of 6

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
193.5	2.5	6.2	Prepare to free end effector	Prepare to free end effector	Payload Station: Retract solar arrays		SEE FIGURE 2.3-23
211.5	18.0	6.3	Trim debris blocking end effector release	Pry debris free; tether LCMS			SAFTEY NOTE: Retain and stow debris if possible -- Use caution to avoid sharp edges
221.5	10.0	6.4	Translate to LCMS port trunnion pin area and monitor RMS and effector release	Translate to LCMS starboard trunnion pin area and monitor RMS and effector release	Payload Station: Release, retract and stow RMS		EV crewmen to stabilize LCMS during RMS release
221.5	38.0						
		7.0	EV Crewmen with MMU's Deploy LCMS				
236.5	15.0	7.1	Tether and transport LCMS to release site, position, stabilize and release	Assist CM1		LCMS to be deployed 7.6 m (25ft) from Orbiter by MMU crewman	RMS cannot be used to deploy LCMS due to end effector damage. SEE FIGURE 2.3-24 (LCMS deployment)
266.5	30.0	7.2	Translate to MMU storage area, doff, recharge and stow MMU	Translate to MMU stowage area, doff, recharge and stow MMU			MMU recharge may not be required, dependent upon EVA duration and mission timeline

TABLE 2.3.4: LCMS EVA TASK COMPLETION PLANS-MISSION SCENARIO NO.1 (Continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: DEPLOY PAYLOAD

Sheet 6 of 6

TIME (Min.)		SEQ.	FUNCTION AND CREW TASK			SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
CUM.	TASK		EVA CM1	EVA CM2	OTHER SUPPORT		
271.0	4.5	7.3	Translate to P/L bay. Remove and stow portable lights	Translate to P/L bay. Stow tools in tool kit and stow tool kit.			
275.0	4.0	7.4	Translate to airlock and ingress	Translate to airlock and ingress			EVA OPERATIONS COMPLETE
275.0	53.5						
TOTAL EVA TIME			TOTAL EVA TIME: 4 HOURS,35 MINUTES				

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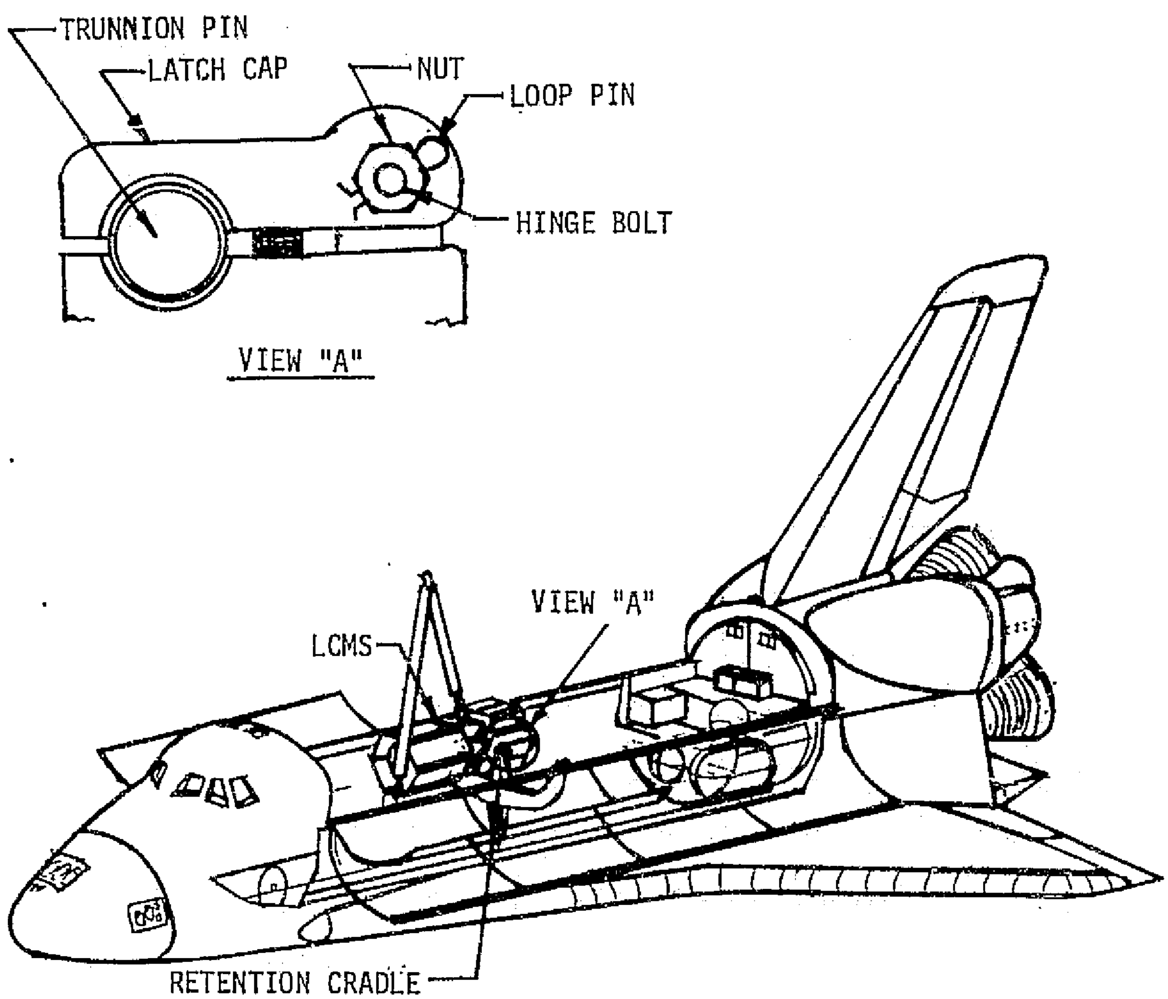


FIGURE 2.3-21: RETENTION CRADLE LATCH MECHANISM RELEASE

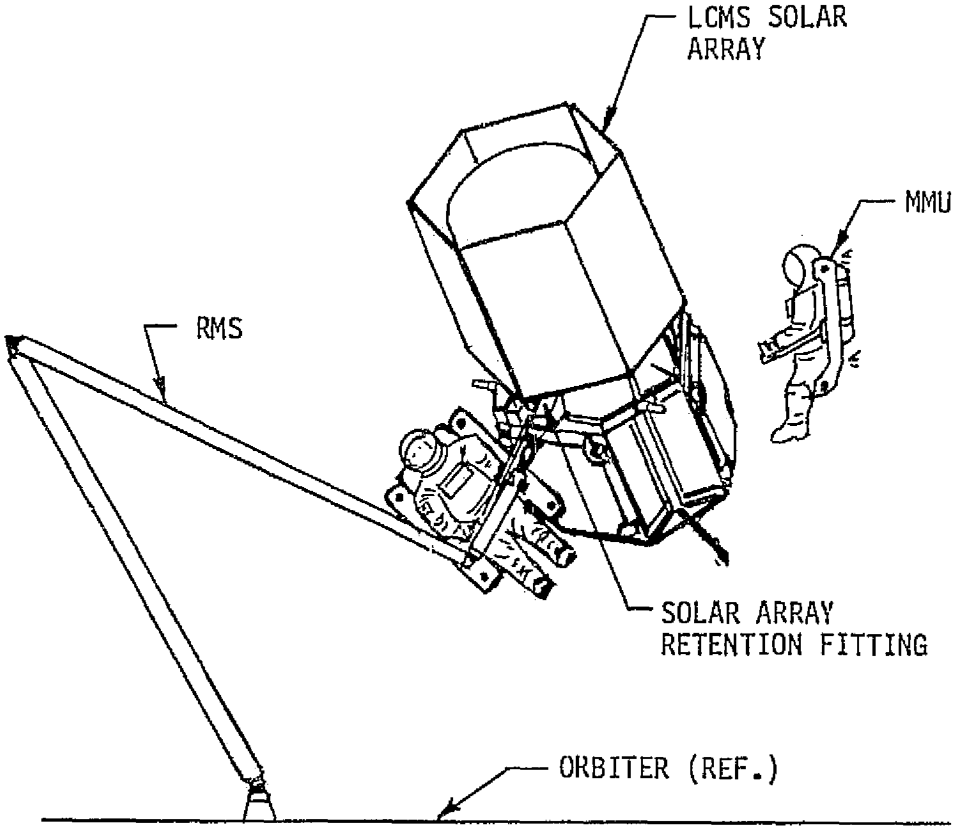


FIGURE 2.3-22: LCMS SOLAR ARRAY RETENTION FITTING RELEASE

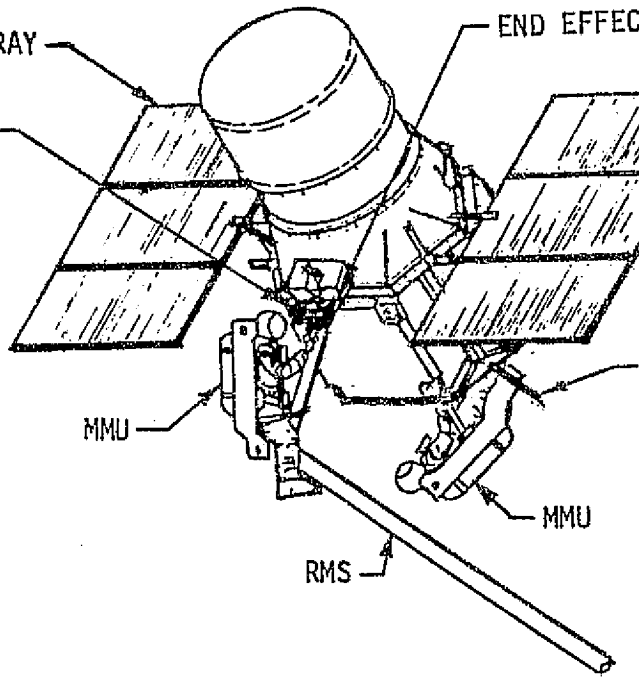


FIGURE 2.3-23: DEBRIS REMOVAL AT RMS END EFFECTOR FITTING

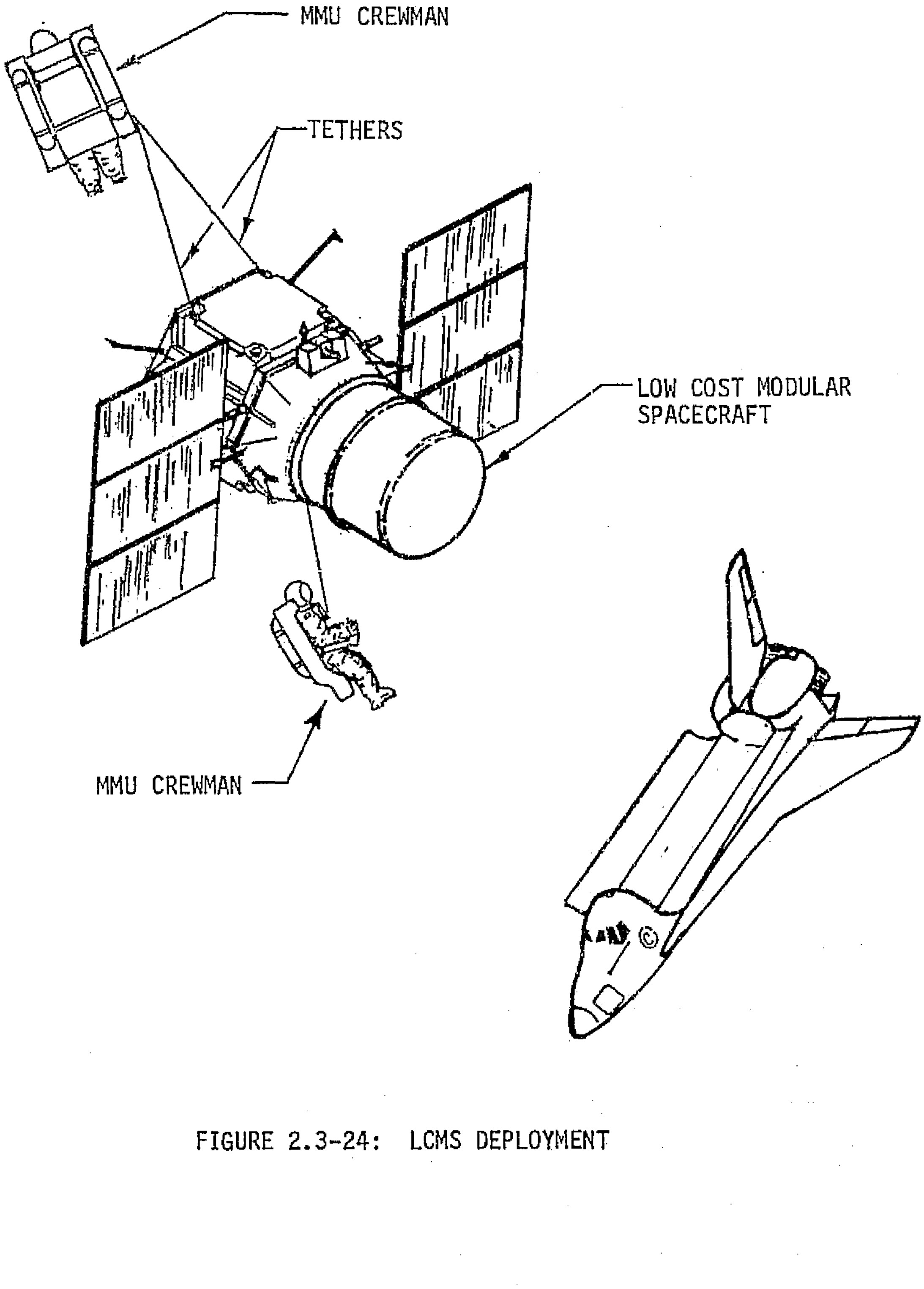


FIGURE 2.3-24: LCMS DEPLOYMENT

2.3.6.3 LCMS EVA Mission Scenario No. 2 - Recover Damaged LCMS

LCMS EVA Mission Scenario No. 2 is based on a selection of contingency EVA tasks from Table 2.3.2. This mission assumes a series of problems occurring during an LCMS refurbishment mission that prevents refurbishment completion and payload bay door closure. Two EVA crew members are required to remove and jettison some of the equipment to permit stowage of the basic LCMS in the payload bay and subsequent door closure. The EVA operations include:

1) Inspect LCMS damage
2) Inspect and diagnose FSS damage
3) Release RMS from damaged LCMS
4) Inspect and verify RMS stowage condition
5) Remove and jettison damaged solar array
6) Stow LCMS in retention cradle
7) Jettison PP.

The major tasks involved and task performance rationale are contained in Table 2.3.5.

TABLE 2.3.5: LCMS EVA Tasks--Mission Scenario No. 2

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
RECOVER DAMAGED LCMS	Perform a two-man "contingency" EVA to release and jettison damaged subsystems and stow the LCMS to allow P/L bay door closure for entry. Initial task is to assess damage, plan overall task and disentangle RMS from LCMS debris.	Assumes impact damage to the LCMS and PP, causing the LCMS to remain extended from the P/L bay, blocking P/L bay door closure.
1. INSPECT LCMS DAMAGE		
• Egress airlock and translate to impact area	Crew translation using handrails along P/L bay door to X_o 1069	Safety precautions must be exercised in proximity of damaged LCMS
• Inspect, diagnose and plan corrective action	Inspect RMS entanglement area, PP/LCMS impact area, LCMS condition and layout work plan	LCMS systems must be turned off
2. INSPECT FSS DAMAGE		
• Translate to FSS area	Crew translation to P/L bay door handrail, then down along PP frame	PP heaters must be turned off
• Inspect and diagnose extent of damage	Translate along PP frame under LCMS and determine condition of PP probes, rotational mechanism, and structural attachments	It is necessary to establish a plan for clearing the P/L bay door closure envelope

TABLE 2.3.5: LCMS EVA Tasks--Mission Scenario No. 2 (continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
3. RELEASE RMS FROM DAMAGED LCMS		
• Translate to tool stowage area and unstow tool kit	Crew translation along P/L bay using handrails, ingress foot restraints and unstow tools and equipment	Foot restraints are permanently mounted at stowage area
• Transfer tools to RMS debris site and attach tethers	Crew translation/tool transport along P/L bay handrail, across RMS to RMS/LCMS probe interface	Attach tethers to avoid EV crewman/debris contact
• Verify that LCMS is powered down	Voice communications check list verification	Damaged solar array must be dormant before next operation begins
• Cut and pry debris from RMS	Unstow tools and attach tool tethers. Cut array debris from RMS wrist and end effector areas. Pry debris away from RMS to permit RMS retraction	Tools required are: Pry bar, chain wrench and metal shears
• Monitor RMS removal operation	Provide stability to damaged solar array while RMS is withdrawn	Requires the use of equipment tethers
4. INSPECT AND VERIFY RMS STOWAGE CONDITION		
• Translate along the length of the RMS and inspect	Crewman translation using RMS handrails. Wrist joint and retention latch fitting must be inspected for damage	Requires one EV crewman
• Translate to PP area and monitor RMS stowage	Crewman translation back along RMS to X_o 1069, then onto PP frame to observe RMS stowage operation	EV crewman assist may be required if wrist joint is damaged

TABLE 2.3.5: LCMS EVA Tasks--Mission Scenario No. 2 (continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
• Translate to each RMS latch and verify status	Crewman translation along RMS to retention latches and verify talk back indicator status	Talkback indicators are located on Orbiter Panel A8
5. <u>REMOVE AND JETTISON DAMAGED LCMS SOLAR ARRAY</u>		
• Inspect and diagnose array condition	Crewman translation across PP frame to LCMS solar array and inspect attach points. Determine how array may be jettisoned	Avoid sharp protrusions on damaged array
• Disconnect array from LCMS at the transition adapter attach point	Attach foot restraints, unstow tools, move solar array to provide fitting access, attach tethers to array, and remove fitting bolts and stow	Tools required are: Double end flare nut wrench set, adjustable wrench, diagonal cutters, and equipment tethers
• Move array from LCMS proximity and jettison	Release equipment tethers from array and jettison array	Two EV crewmen required for safe handling of array
6. <u>STOW LCMS IN RETENTION CRADLE</u>		
• Translate to LCMS/PP interface and assist LCMS docking release	Crewman translation along LCMS to PP interface. Attach equipment tethers to LCMS. Cut and pry debris from interface area and release LCMS	Requires two EV crewmen. Tools required are: shears, pry bar and chain wrench
• Move LCMS into P/L bay and RC	EV crewmen transfer LCMS to RC, guiding trunnion pins into RC latches	RC heaters must be turned off

TABLE 2.3.5: LCMS EVA Tasks--Mission Scenario No. 2 (continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
• Monitor closure of RC latches and verify proper LCMS stowage	With one EV crewman positioned near the port P/L retention latch and the other near the starboard latch, observe latches and monitor closure	Visual observation of latch actuation to be verified by talk back indicators on Orbiter. Panel A7
7. JETTISON PP		
• Translate to PP base and monitor rotation attempt	EV crewmen to translate along LCMS, to area of PP and visually monitor attempt to rotate damaged PP into Orbiter P/L bay	PP must rotate to provide clearance for P/L bay door closure. If PP does not rotate proceed to next step
• Transfer tools to PP/Orbiter port trunnion latch	Crewmen translate along PP frame to port trunnion latch. Attach tethers and prepare tools for use	Tools required are: Socket set, ratchet wrench, 8" ratchet extension, pliers, and double end flare nut wrench set
• Remove bolts and release trunnion	Cut and remove safety wire, remove bolts and remove trunnion latch cap	Stow all loose parts
• Repeat for starboard trunnion latch removal	Translate to starboard side and remove bolts and trunnion latch cap	Stow all loose parts
• Move PP from installed position and jettison	Translate into P/L bay, with one crewman at starboard trunnion and one at port trunnion. Push PP from P/L bay and jettison	Crew tether point required for stabilization
• Transfer tools and equipment to stowage area and stow	Translate to stowage area, don foot restraints, stow tools and equipment and doff foot restraints	One EV crewman required for stowage task. Second EV crewman may proceed to final step
• Translate to airlock and ingress		TASK COMPLETE

2.3.6.4 LCMS EVA Task Completion Plans - Mission Scenario No. 2

Preliminary timelines and procedures developed for the LCMS mission scenario no. 2 are provided in Table 2.3.6. Assumptions associated with the mission scenario include the following:

- Sufficient mobility aids (handholds, handrails) are provided by the payload and/or Shuttle Orbiter to access the LCMS/PP from the airlock.
- Realizing the possible requirement for a contingency EVA, crew mobility aids are provided by the payload for access to each LCMS associated area.
- Since design details were not available for many of the LCMS subsystems, conceptual designs were developed by the contractor to implement procedures development.
- Two qualified crewmembers are available for conducting EVA. A third crewmember is available to perform minimal Payload Station (PS) EV supporting functions.
- Foot restraints (1 pair) and mobility aids are provided at the tool and equipment stowage area.
- Sufficient pallet lighting is provided by the Orbiter and payload to perform EV tasks.

This mission scenario involves a contingency EVA situation based upon the premise that an LCMS, being retrieved by the RMS, impacts the PP with sufficient force to jam the PP, cause structural failure of the LCMS solar array and equipment damage which entangles the RMS in the debris. The RMS is rendered inoperable and must be stowed, while the solar array and PP must be jettisoned. The basic LCMS is recovered for ground refurbishment. Refer to Figures 2.3-25 through 2.3-28.

TABLE 2.3.6: LCMS EVA TASK COMPLETION PLANS-MISSION SCENARIO NO. 2

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: RECOVER DAMAGED LCMS MODE: UNAIDED EVA Sheet 1 of 6

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
		1.0	Prepare for two-man contingency EVA to inspect and recover an LCMS damaged during an RMS recovery attempt.				
4.5	4.5	1.1	Egress airlock and translate to impact area	Egress airlock and translate to impact area		P/L bay door handrails	SAFETY NOTE: Exercise extreme caution in proximity of damaged LCMS
13.5	9.0	1.2	Inspect and diagnose LCMS condition	Inspect and diagnose positioning platform condition	Payload station: Turn PP heaters off.		Identify extent of damage to LCMS/PP mechanism and LCMS arrays
21.5	8.0	1.3	Formulate work plan	Assist CM1			SEE FIGURE 2.3-25
21.5	21.5						
		2.0	Disentangle RMS from Damaged LCMS				
26.5	5.0	2.1	Translate along RMS to debris area and attach tethers for stabilization.	Translate to tool stowage, ingress foot restraints, unstow tools and equipment and egress foot restraints	Payload Station: Verify that LCMS is powered down	RMS handrail	
29.0	2.5	2.2	Begin planned task of RMS disentanglement	Transfer tools to worksite and attach tethers		EMU Tether	Tools required are: Pry bar, metal shears and chain wrench. Use come-along if required

TABLE 2.3.6: LCMS EVA TASK COMPLETION PLANS-MISSION SCENARIO NO. 2 (Continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: RECOVER DAMAGED LCMS

Sheet 2 of 6

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
47.0	18.0	2.3	Cut debris from RMS wrist joint and end effector areas.	Assist CM1 by use of pry bar and chain wrench to pry array free.		EMU tether	Collect and stow debris if possible. SEE FIGURE 2.3-26
56.5	9.5	2.4	Translate to P/L bay door handrail area and monitor RMS extraction from debris	Attach tethers to damaged array to provide stability during RMS extraction	Payload station: Activate and extract RMS. Postion RMS parallel to stowage position.	P/L bay door handrails	LCMS is restrained by PP
56.5	35.0						
		3.0	Inspect, Verify RMS Stowage Condition and Stow				
60.0	3.5	3.1	Translate along RMS and inspect damage to RMS wrist joint and end effector	Proceed to solar array area and prepare for next operation		RMS handrail	
69.5	9.5	3.2	Translate to PP frame and monitor RMS stowage	Same as above	Payload station: Stow RMS. Verify talkback indicator status on Orbiter Panel A8	PP frame structure	EV crewman assist may be required during RMS stowage if wrist joint damage is extensive
77.0	7.5	3.3	Translate to each RMS latch and verify status	Same as above		RMS handrail	
77.0	20.5						

TABLE 2.3.6: LCMS EVA TASK COMPLETION PLANS-MISSION SCENARIO NO. 2 (Continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: RECOVER DAMAGED LCMS

Sheet 3 of 6

TIME (Min.)		SEQ.	FUNCTION AND CREW TASK			SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
CUM.	TASK		EVA CM1	EVA CM2	OTHER SUPPORT		
		4.0	Remove and Jettison damaged LCMS Solar Array				
84.5	7.5	4.1	Translate to solar array attachment area on transition adapter and attach foot restraints and tethers	Define jettison procedures		LCMS transition adapter	Avoid contact with array protrusions
88.5	4.0	4.2	Attach tethers to hold array in a stabilized position providing access to attachment fitting interface with LCMS	Assist CM1		Equipment tethers	
106.5	18.0	4.3	Remove bolts and base cover, disconnect array structural attachments and cut cable	Collect and stow loose parts		Carry-all container for loose parts stowage	Tools required are: Double end flare nut wrench set, adjustable wrench, and *bolt cutters. SEE FIGURE 2.2-27
115.0	8.5	4.4	Move array from proximity of Orbiter, detach tethers and jettison	Assist CM1		EMU tether for stabilization	
115.0	38.0						

*EVA item required to complete LCMS Mission Scenario No. 2 to be provided by payload.

TABLE 2.3.6: LCMS EVA TASK COMPLETION PLANS-MISSION SCENARIO NO. 2 (Continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: RECOVER DAMAGED LCMS

Sheet 4 of 6

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	EVA CM2	OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
		5.0	Move LCMS from PP and Stow in RC for Ground Refurbishment				
119.5	4.5	5.1	Translate to LCMS/PP interface, attach tethers to LCMS for stabilization and handling	Assist CM1		EMU tether	
131.5	12.0	5.2	Cut, pry and remove debris to free LCMS from PP	Assist CM1		PP docking probes	Tools required are: Metal shears, pinch bar, and chain wrench. Use come-along if required
138.5	7.0	5.3	Monitor attempt to release LCMS from docked position. Assist as required to accomplish undocking	Monitor and assist CM1	Payload station: Cycle retention latch switch		
157.0	18.5	5.4	Transfer LCMS into P/L bay and stow in RC	Assist CM1		RC heaters must be turned "off"	Proper alignment of LCMS trunnion pins with RC latches is required
159.0	2.0	5.5	Monitor closure of port RC retention latch	Monitor closure of starboard RC retention latch	Payload Station: Cycle switch on Orbiter Panel A7 to close retention latches	Verify actuation by talkback indicators on Orbiter Panel A7	
159.0	44.0						

TABLE 2.3.6: LCMS EVA TASK COMPLETION PLANS-MISSION SCENARIO NO. 2 (Continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: RECOVER DAMAGED LCMS

Sheet 6 of 6

TIME (Min.) CUM.	TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	EVA CM2	OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
		6.0	Jettison Positioning Platform (PP) that is Blocking Payload Bay Door Closure				
162.5	3.5	6.1	Translate to aft port end of LCMS and monitor PP rotation attempt	Translate to aft starboard end of LCMS and monitor PP rotation attempt	Payload Station: Position switch to stow the 90° lift actuation mechanism. Return RC heater power to "on" and PP power to "off"	Stowed LCMS	
167.0	4.5	6.2	Translate to X_o 1069 to port fixed attach fitting and connect tethers for stabilization	Assist CM1		Payload fixed attach fitting and payload trunnion (port and starboard)	Tools required are: Socket set, ratchet wrench, 8" ratchet extension, diagonal cutters, and double end flare nut wrench set
175.0	8.0	6.3	Loosen nut on forward attach bolt and swing forward. Swing journal cap aft to clear trunnion	Assist CM1		Same as above	SEE FIGURE 2.3-28
187.5	12.5	6.4	Repeat steps 6.2 and 6.3 for starboard fitting	Assist CM1		Same as above	
190.0	2.5	6.5	Disconnect/cut power cable	Assist CM1		Orbiter power cable	

TABLE 2.3.6: LCMS EVA TASK COMPLETION PLANS-MISSION SCENARIO NO. 2 (Continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: RECOVER DAMAGED LCMS

Sheet 6 of 6

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
202.5	12.5	6.6	Translate to P/L bay under port PP trunnion and attach EMU tether. Push PP trunnion from Orbiter attach fitting journal and jettison PP	Translate to P/L bay under starboard PP trunnion and attach EMU tether. Assist CM1		EMU tether	(Reference Figure 2.3-28)
207.0	4.5	6.7	Transfer tools and equipment to stowage area, ingress foot restraints and stow	Translate to airlock and ingress		P/L bay handrails	
211.0	4.0	6.7	Egress foot restraints, translate to airlock and ingress				EVA OPERATIONS COMPLETE
211.0 TOTAL EVA TIME	52.0		TOTAL EVA TIME 3 Hours, 31 Minutes				

SPACE SHUTTLE EVA

MDC W0014
2 JUNE 1976

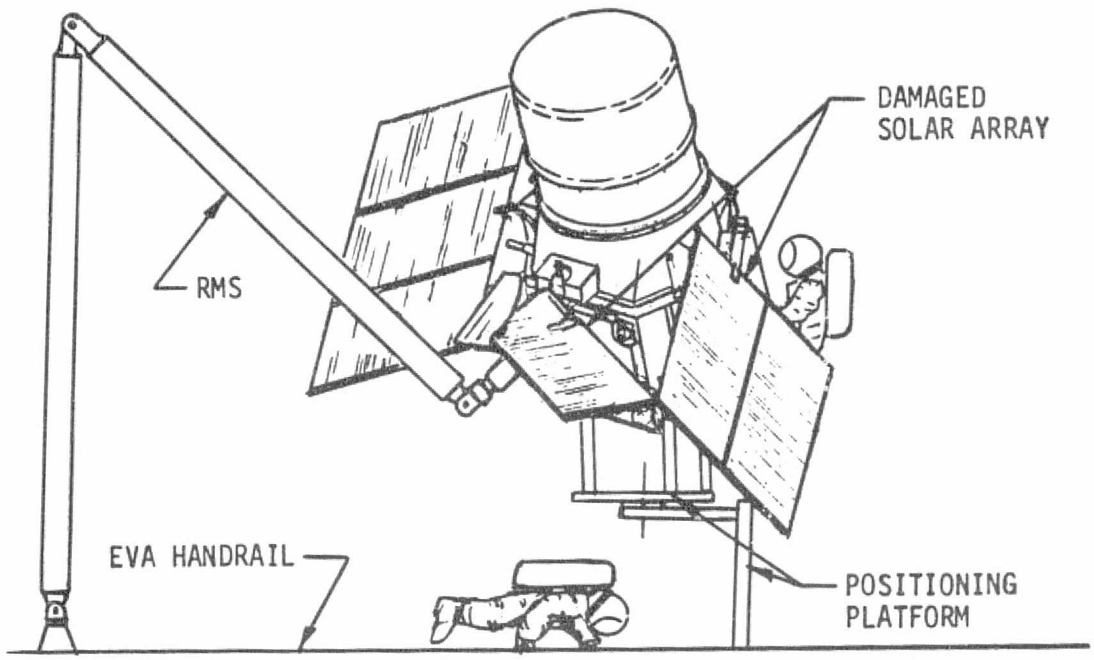


FIGURE 2.3-25: INSPECT DAMAGED LCMS AND POSITIONING PLATFORM

SPACE SHUTTLE EVA

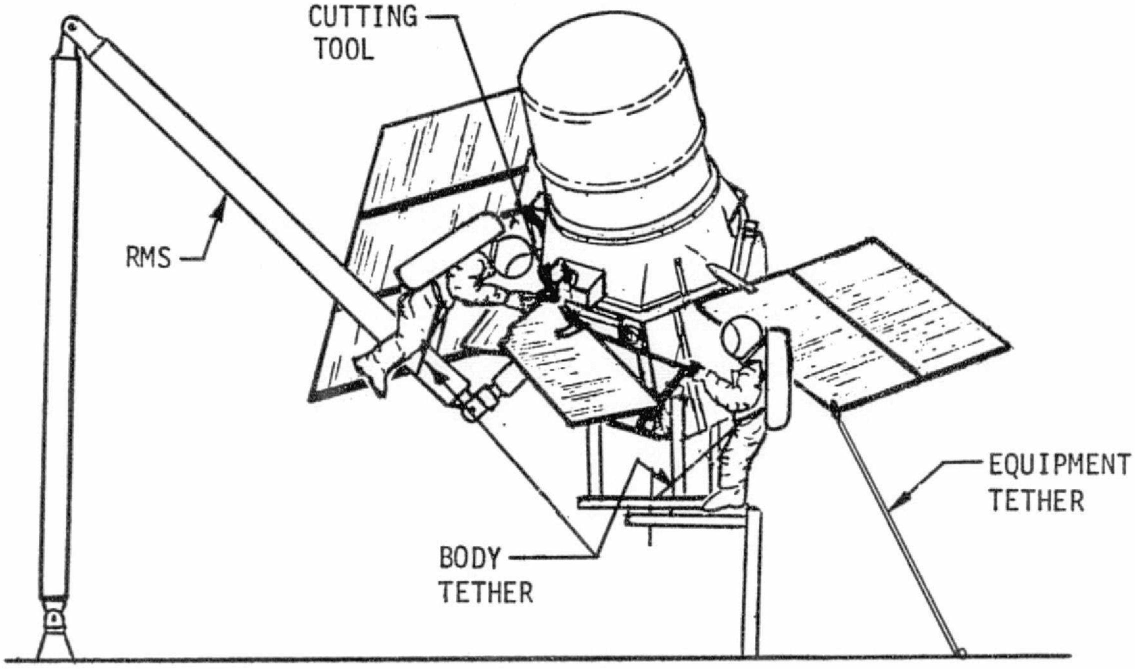


FIGURE 2.3-26: DISENTANGLE RMS FROM SOLAR ARRAY DEBRIS

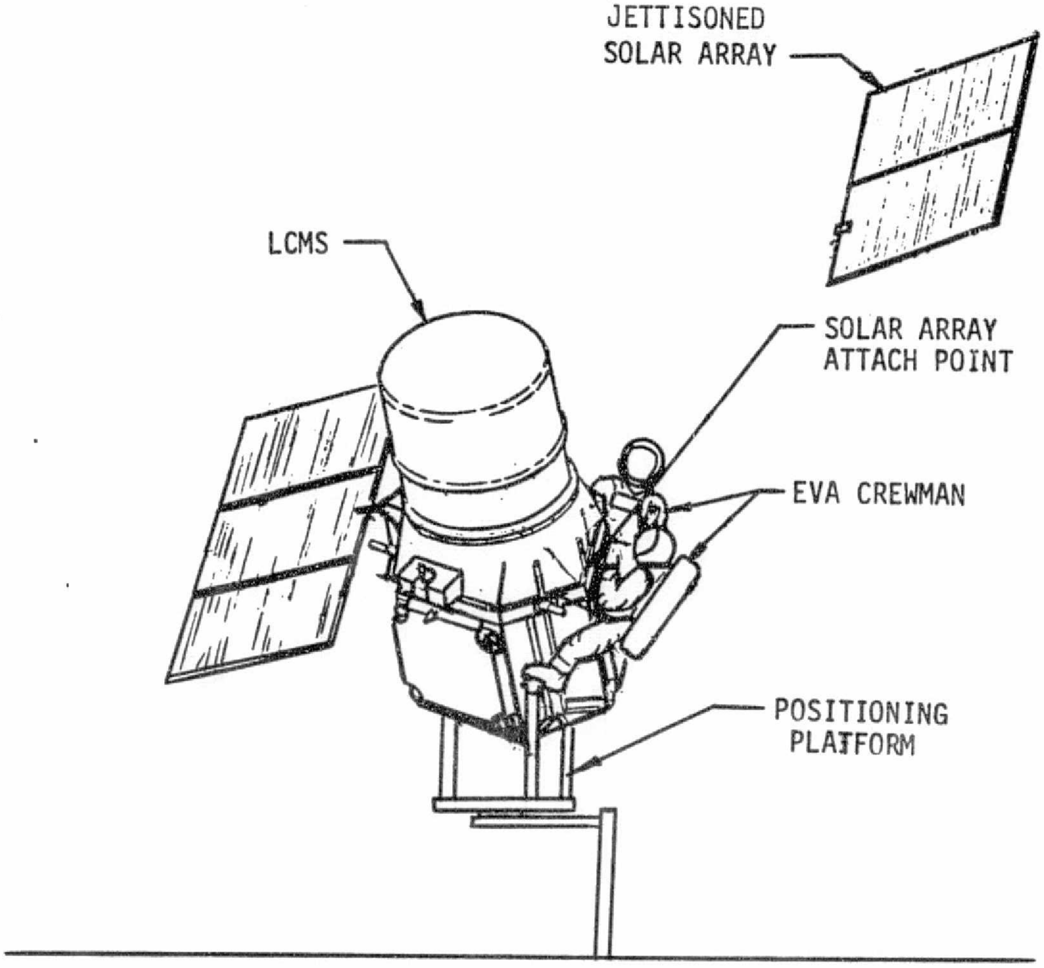


FIGURE 2.3-27: RELEASE AND JETTISON DAMAGED SOLAR ARRAY

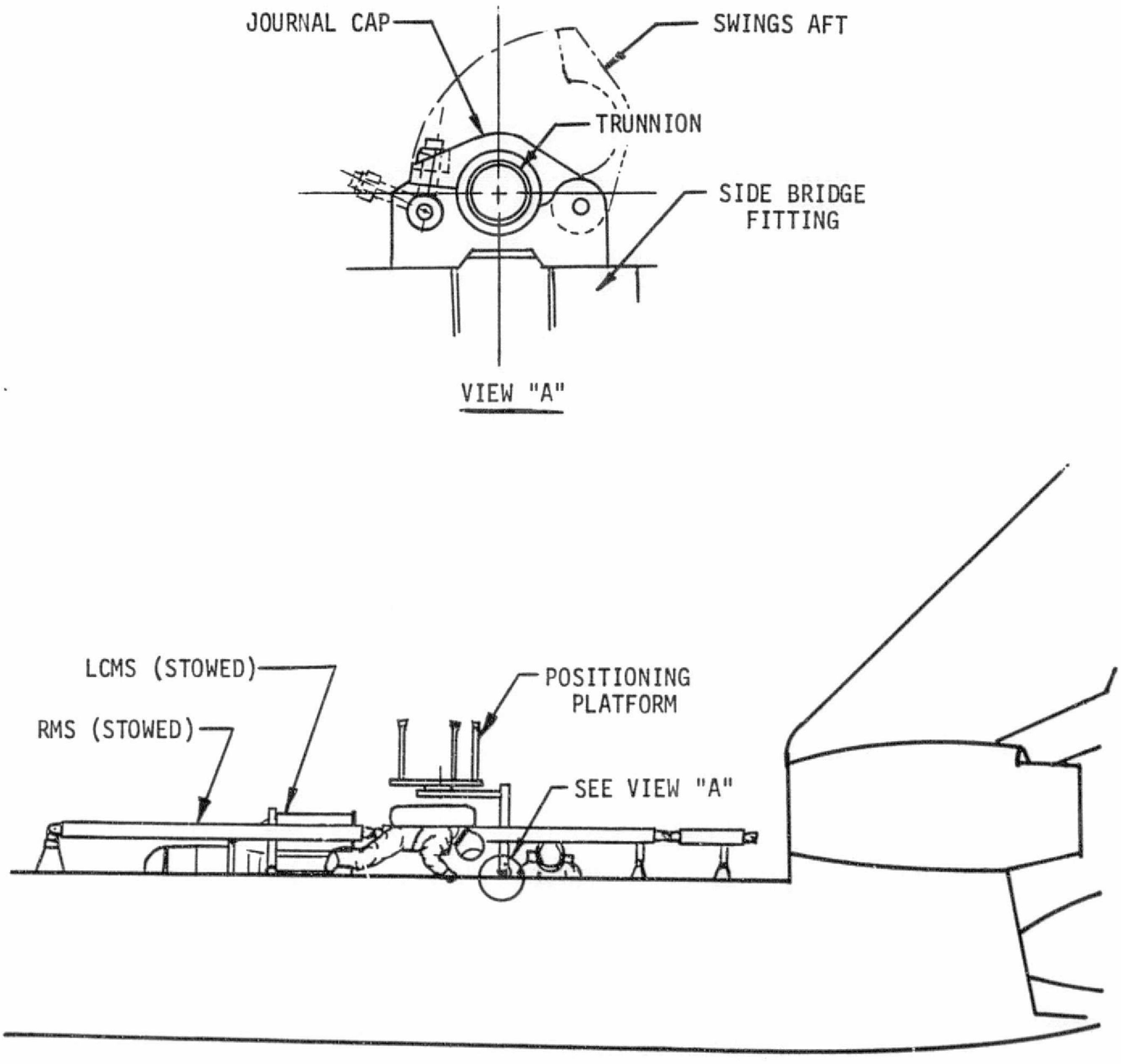


FIGURE 2.3-28: REMOVE AND JETTISON POSITIONING PLATFORM

2.3.6.5 LCMS EVA Mission Scenario No. 3 - Refurbish LCMS

This scenario is based on a selection of potential EVA tasks from Table 2.3.2. It assumes completion of a refurbishment mission using EVA and the RMS in lieu of the currently planned FSS. Handling of the LCMS and the replacement module depend upon the RMS, while the EVA crewmen direct the tasks, made and break all connections and assure proper task completion. Replacement and spent modules are stowed on a pallet in the payload bay. The EVA operation includes:

1) Retrieve LCMS and connect Orbiter to LCMS power cables
2) Erect portable work stations
3) Remove spent modules and place in temporary storage
4) Install refurbishment modules
5) Stow spent modules for return to earth
6) Stow portable work stations
7) Deploy LCMS

The major tasks involved and task performance rationale are contained in Table 2.3.7.

TABLE 2.3.7: LCMS EVA Tasks--Mission Scenario No. 3

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
REFURBISH LCMS	Perform a two-man EVA to conduct LCMS on-orbit refurbishment operations. The operations consist of LCMS capture, refurbishment and redeployment.	Assumes deletion of the SPMS and accomplishment of operations through a combination of EVA and RMS operations
1. <u>RETRIEVE LCMS AND CONNECT ORBITER TO LCMS POWER CABLES</u>		
• RMS capture and docking of LCMS to PP	Normal RMS payload retrieval	EVA not required for retrieval
• Egress airlock and translate to PP	One EV crewman translation using handrails along P/L bay door to X_o 1069. Second EV crewman proceed to tool storage area	Crew tether point required for stabilization at umbilical worksite
• Connect electrical power umbilical	Unstow and connect Orbiter to LCMS power umbilical	Requires one EV crewman
2. <u>ERECT PORTABLE WORK STATION</u>		
• Translate to equipment stowage area and unstow portable work station	Ingress foot restraints, unstow portable work stations and tools	Requires two EV crewmen

TABLE 2.3.7: LCMS EVA Tasks--Mission Scenario No. 3 (continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
• Transfer work stations to work-site and install	Crewman hand-carry tools to worksite. RMS transfer of portable work stations. Assemble and attach work stations at worksite	One EV crewman at worksite and one at stowage area during equipment transfer phase.
3. REMOVE SPENT MODULES AND PLACE IN TEMPORARY STORAGE		
• Ingress work stations and set-up for module removal	Translate to work area, ingress work stations, unstow and attach tool tethers, and prepare for module removal	Two EV crewmen required, one on each side of module.
• Detach module	Disconnect module	Use motor unit
• Remove module and transfer to temporary storage site	Attach RMS, withdraw module and transfer to stowage area	EV crewmen to observe and direct the operation
• Translate to storage site and attach spent module	Translate along P/L bay door hand-rail to stowage position, accept module from RMS and temporarily stow with equipment tethers	Repeat above steps for each module to be replaced

TABLE 2.3.7: LCMS EVA Tasks--Mission Scenario No. 3 (continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
4. INSTALL REFURBISHMENT MODULES		
• Unstow module from stowage pallet	Remove replacement module from stowage position for RMS transfer	Requires only one EV crewman to unstow module
• Transfer module to LCMS	Transfer module to worksite and position for pre-installation inspection	Inspection requires removal of protective covers and a physical damage assessment
• Install and attach module	RMS to insert and hold module while EV crewmen attach fasteners	Fasteners must be attached to hold module in the installed position
• Inspect and verify installation	The installation inspection is to verify that the module is properly installed and that all connections have been made in readiness for activation	Repeat above steps for each module to be replaced
5. STOW SPENT MODULES FOR RETURN TO EARTH		
• Translate to stowage pallet	Translate to stowage area using P/L bay door handrails	Two EV crewmen required for stowage task completion
• Move spent modules from temporary storage to stowage pallet and secure for return to earth	Detach temporary stowage tethers, move spent modules into stowage position and stow for entry	NOTE: From this point EV crewmen perform separate tasks

TABLE 2.3.7: LCMS EVA Tasks--Mission Scenario No. 3 (continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
6. STOW PORTABLE WORK STATIONS		
• Translate to worksite	One EV crewman translates to worksite along P/L bay handrails	First EV crewman performs stowage task
• Remove portable work stations	Detach, fold and prepare work stations for stowage	Work station is designed for quick/compact stowage
• Transfer work stations and tools to stowage area	RMS transfer of work stations. EV crewman hand carries tools to stowage area	Equipment tethers used during transfer operations
• Stow equipment	Stow work stations and tools for entry	First crewman may begin ingress activity
7. DEPLOY LCMS		
• Translate to PP	EV crewman translate to PP	Second EV crewman prepares LCMS for deployment
• Disconnect electrical power umbilical	Disconnect and stow Orbiter to LCMS power umbilical	Requires tether attach point for EV stabilization
• Attach RMS to LCMS Shuttle capture drogue	Monitor RMS attachment operation	
• Release holddown fixtures	Operate mechanical probe release mechanism	Operation conducted from beneath LCMS near PP interface

TABLE 2.3.7: LCMS EVA Tasks--Mission No. 3 (continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
• Deploy LCMS with RMS	Move LCMS to deployment position using the RMS	Monitor deployment activity and prepare area for entry
• Translate to airlock and ingress (Both crewmen)		TASK COMPLETE

2.3.6.6 LCMS EVA Task Completion Plans - Mission Scenario No. 3

Preliminary timelines and procedures developed for the LCMS mission scenario no. 3 are provided in Table 2.3.8. Assumptions associated with the mission scenario include the following:

- Sufficient mobility aids (handholds, handrails) are provided by the payload and/or Shuttle Orbiter to access the LCMS/PP from the airlock.
- Given the requirement for a potential planned EVA, crew mobility aids are provided by the payload for access to each LCMS associated area.
- Since design details were not available for many of the LCMS subsystems, conceptual designs were developed by the contractor to implement procedures development.
- Two qualified crewmembers are available for conducting EVA. A third crewmember is available to perform minimal Payload Station (PS) EV supporting functions.
- Spare LCMS modules are provided as pallet mounted equipment. The spares are attached to the pallet structure.
- Foot restaints (1 pair) and mobility aids are provided at the spares stowage pallet.
- Sufficient pallet lighting is provided by the Orbiter and payload to perform EV tasks.

In this scenario LCMS module replacement is accomplished by RMS aided EVA, thereby deleting the necessity for the automated refurbishment systems (SPMS) and automated positioning platform. The LCMS is docked to a modified positioning platform that rotates as a carousel to permit RMS/EVA access to each module. New and spent modules are released/attached by the EV crewmen (Figure 2.3-29) and transferred by the RMS (See Figures 2.3-30 through 2.3-32).

TABLE 2.3.8: LCMS EVA TASK COMPLETION PLANS-MISSION SCENARIO NO.3

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: REFURBISH LCMS | MODE: EVA WITH RMS | Sheet 1 of 6

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	EVA CM2	OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
		1.0	Prepare for two-man potential planned EVA, retrieve and dock LCMS to modified positioning platform (PP)				
		1.1	Complete EVA preparation	Complete EVA preparation	Payload Station: RMS capture and docking of LCMS to PP	RMS/PP	Payload capture and docking completed prior to crewman egress from airlock
3.5	3.5	1.2	Egress airlock and translate to PP	Egress airlock and translate to tool storage		P/L bay door handrail	SEE FIGURE 2.3-29
9.0	5.5	1.3	Connect Orbiter to LCMS power umbilical	Ingress foot restraints, unstow tools and prepare for transfer to worksite		Orbiter power umbilical	
17.0	8.0	1.4	Assist RMS end effector exchange	Same as above	Payload Station: Maneuver RMS to exchange end effectors		
17.0	17.0						
		2.0	Unstow, transfer Portable Work Stations				
22.0	5.0	2.1	Inspect LCMS to verify readiness for refurbishment operation	Unstow portable work stations and prepare for transfer to work site			*Portable EVA work stations transported to worksite by RMS

*EVA equipment required to complete LCMS Mission Scenario No. 3 to be provided by payload.

TABLE 2.3.8: LCMS EVA TASK COMPLETION PLANS-MISSION SCENARIO NO. 3 (Continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: REFURBISH LCMS

Sheet 2 of 6

TIME (Min.) CUM.	TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	EVA CM2	OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
29.0	7.0	2.2	Receive first portable work station at work site and tether for temporary storage	Attach portable work station for RMS transfer. Connect safety tether	Payload Station: Operate RMS to transfer portable work stations	Equipment tethers	EVA workstations transported by RMS; positioned and deployed by crewmen
39.0	10.0	2.3	Repeat for second work station	Same as above	Same as above		
45.0	6.0	2.4	Attach and deploy work stations near port and starboard sides of LCMS	Hand carry tools to work site and assist CM1 in attaching and deploying work stations			Portable work station attach provisions designed into structure at required locations
45.0	28.0						
		3.0	Remove Spent LCMS Modules and replace refurbishment modules				
49.0	4.0	3.1	Ingress port work station, unstow tools and attach tethers	Ingress starboard work station and unstow tools		LCMS module interface	*Motor unit required
58.0	9.0	3.2	Continue worksite preparation	Assist RMS attachment to ACS spent module and actuate end effector latches	Payload Station: Operate RMS to attach to module	RMS end effector, wrist assembly and end effector latches	Manually actuated latches provided on RMS end effectors
59.0	1.0	3.3	Release port resupply latch mechanism	Release starboard resupply latch mechanism		ACS module release mechanism	SEE FIGURE 2.3-30

*EVA item required to complete Mission Scenario No. 3 to be provided by payload.

TABLE 2.3.8: LCMS EVA TASK COMPLETION PLANS-MISSION SCENARIO NO. 3 (Continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: REFURBISH LCMS

Sheet 3 of 6

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
62.5	3.5	3.4	Assist RMS in ACS removal from LCMS	Tether ACS module to RMS arm			
67.5	5.0	3.5	Inspect module and RMS for transfer status	Translate to LCMS module stowage rack and ingress foot restraints	Payload Station: Operate RMS to transfer module	Module stowage rack	Module stowage rack provides stowage for 3 modules and one additional unit for module handling. SEE FIGURE 2.3-31
79.5	12.0	3.6	Confirm LCMS configured to accept new ACS module	Assist RMS in stowing ACS module, lock module in stowage rack and release end effector latches	Payload Station: Operate RMS to stow ACS module	Module latches on stowage rack	Module latches on stowage rack are manually actuated by crewman
84.5	5.0	3.7	Rest	Tether new ACS module to RMS arm, assist RMS attachment to ACS and release module stowage rack latches	Payload Station: Maneuver RMS to new ACS module stowage and engage		
90.0	5.5	3.8	Rest	Assist retraction of ACS module from stowage rack. Translate to LCMS starboard workstation	Payload Station: Operate RMS to transfer new ACS module to LCMS		
97.0	7.0	3.9	Assist RMS in positioning new ACS in LCMS, secure port resupply latch mechanism and release end effector latches	Rest--secure starboard resupply latch mechanism and release ACS tether	Payload Station: Retract RMS to clear LCMS rotation envelope		

TABLE 2.3.8: LCMS EVA TASK COMPLETION PLANS-MISSION SCENARIO NO. 3 (Continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: REFURBISH LCMS

Sheet 4 of 6

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
99.5	2.5	3.10	Manually reclock LCMS positioning platform to access next module	Release LCMS positioning platform and assist CM1	Payload Station: Initiate ACS checkout procedures	Positioning platform	Positioning platform (with LCMS) is rotated by crewmen using motor unit to access each replacement module SEE FIGURE 2.3-32
150.0	50.5	3.11	Repeat steps 3.2 through 3.9 for Power module				
200.5	50.5	3.12	Repeat steps 3.2 through 3.9 for C&DH module				
205.5	5.0	3.13	Disconnect LCMS power umbilical from Orbiter	Prepare EVA equipment stowage for reentry		Power umbilical and stowage fixture/lacthes	Stow power umbilical for reentry
205.5	160.5						
		4.0	EVA Equipment stowage				
213.0	7.5	4.1	Translate to EVA equipment stowage and ingress foot restraints	Fold, release and attach starboard EVA workstation to RMS end effector	Payload Station: Maneuver RMS		
216.0	3.0	4.2	Remove EVA workstation from RMS and stow	Prepare LCMS for deployment	Same as above		Confirm LCMS modules secure
224.0	8.0	4.3	Prepare EVA equipment for reentry	Fold, release and attach port EVA workstation to RMS end effector	Same as above		

TABLE 2.3.8: LCMS EVA TASK COMPLETION PLANS-MISSION SCENARIO NO.3 (Cotinued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: REFURBISH LCMS

Sheet 5 of 6

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
228.0	4.0	4.4	Remove EVA workstation from RMS and stow	Prepare LCMS for deployment	Payload Station: Complete pre-release checkout of LCMS functions		Confirm operational status of replacement modules
236.0	8.0	4.5	Assist RMS end effector exchange	Same as above			
238.5	2.5	4.6	Check and confirm used LCMS modules secure for reentry	Assist RMS end effector attachment to LCMS for deployment			Standard payload end effector
238.5	33.0						
		5.0	Release and Deploy LCMS				
242.0	3.5	5.1	Translate to airlock area and standby for LCMS deployment	Translate to airlock area and standby	Payload Station: Release LCMS/PP latch mechanism	Handrails, airlock	
257.0	15.0	5.2	Monitor LCMS deployment	Monitor LCMS deployment	Payload Station: Maneuver RMS		Standby EVA for assist operations if necessary
263.0	6.0	5.3	Secure PP latch mechanisms for reentry	Inspect and confirm payload bay and EVA equipment configured for reentry	Payload Station: Confirm payload release		

TABLE 2.3.8: LCMS EVA TASK COMPLETION PLANS-MISSION SCENARIO NO. 3 (Continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: REFURBISH LCMS

Sheet 6 of 6

TIME (Min.)		SEQ.	FUNCTION AND CREW TASK			SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
CUM.	TASK		EVA CM1	EVA CM2	OTHER SUPPORT		
268.0	5.0	5.4	Translate to airlock and ingress	Translate to airlock and ingress			EVA OPERATIONS COMPLETE
268.0 TOTAL EVA TIME	29.5		TOTAL EVA TIME 4 Hours,28 minutes				

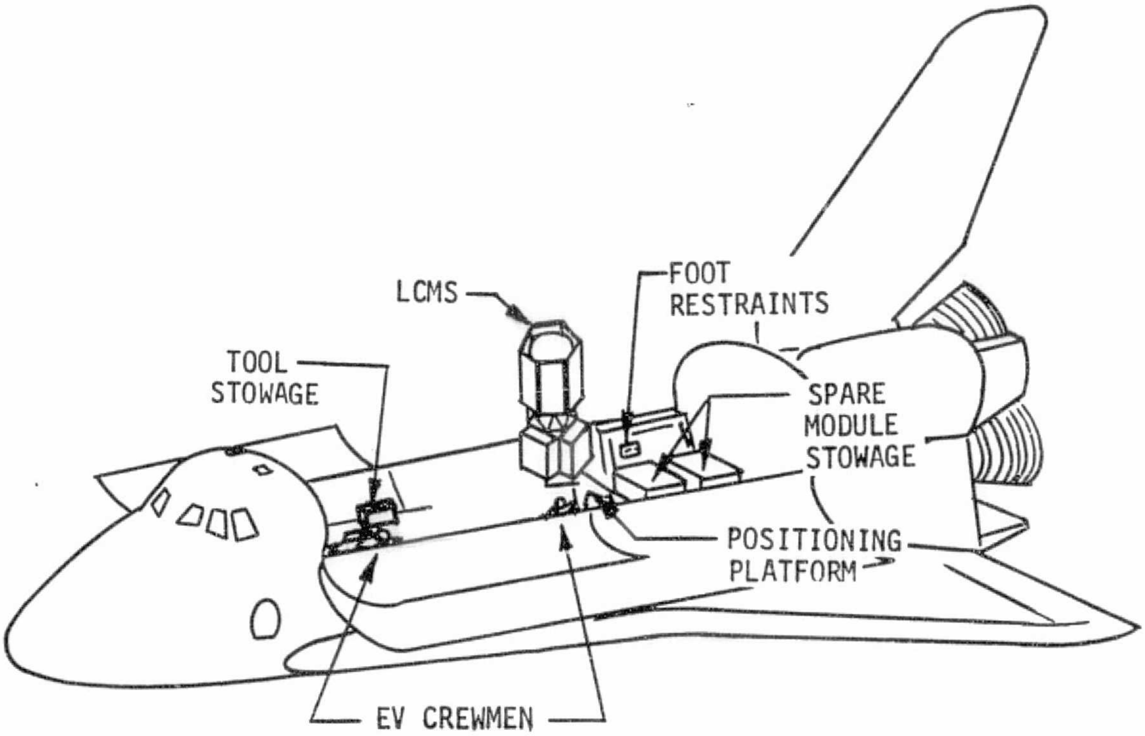


FIGURE 2.3-29: PREPARATION FOR REFURBISHMENT EVA OPERATIONS

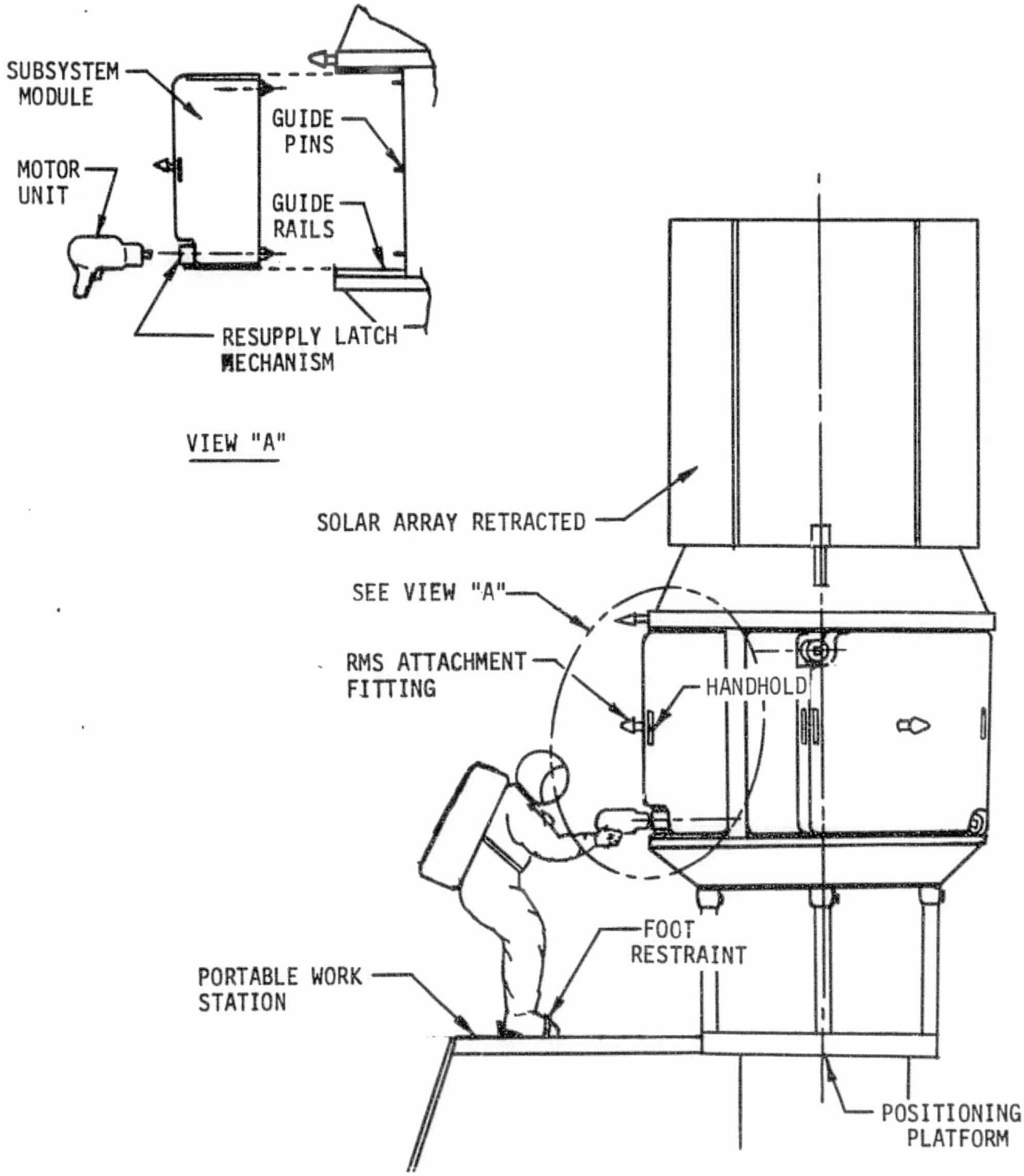


FIGURE 2.3-30: LCMS RESUPPLY LATCH MECHANISM OPERATION

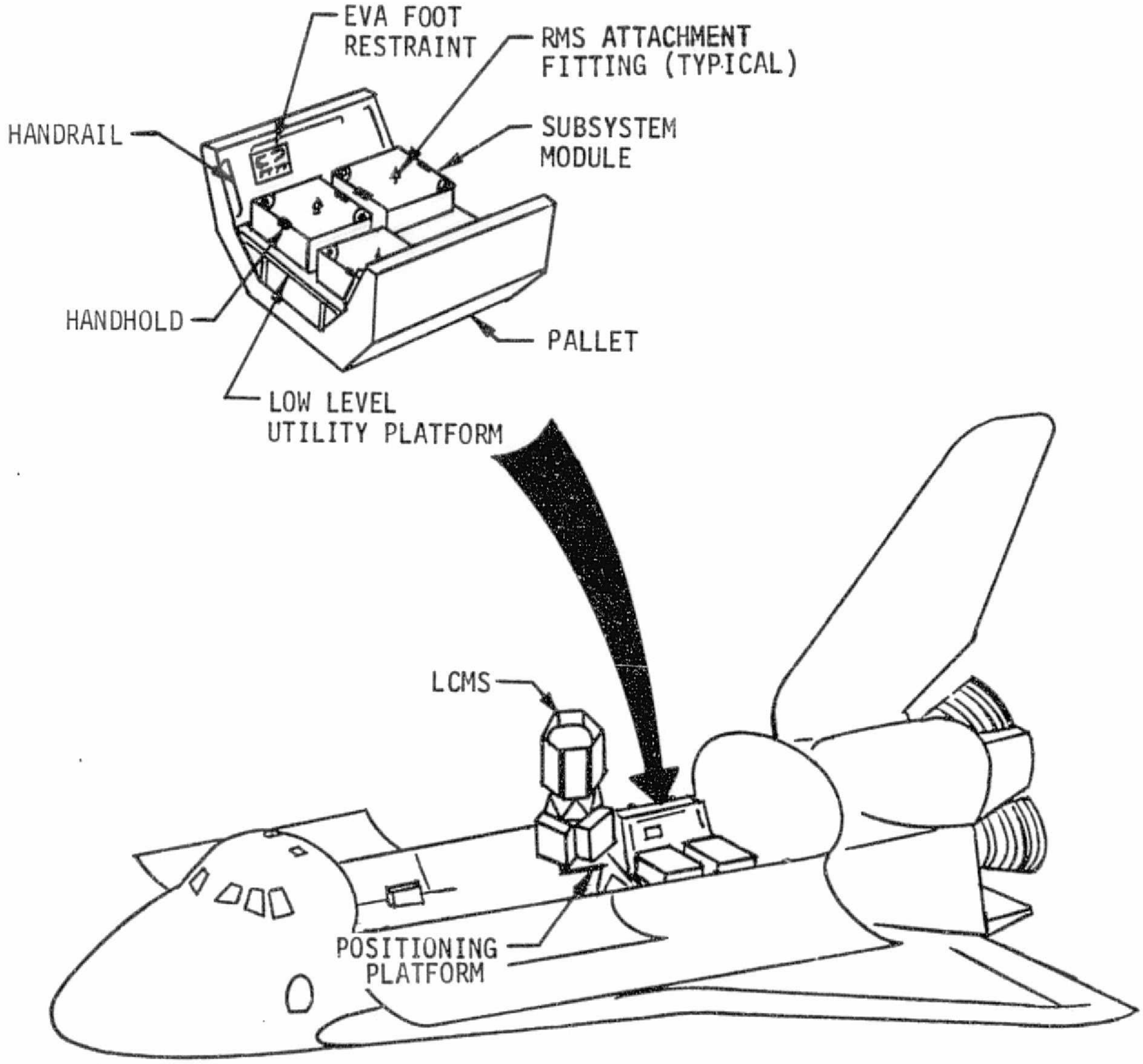


FIGURE 2.3-31: SPARE SUBSYSTEM MODULE STOWAGE CONCEPT

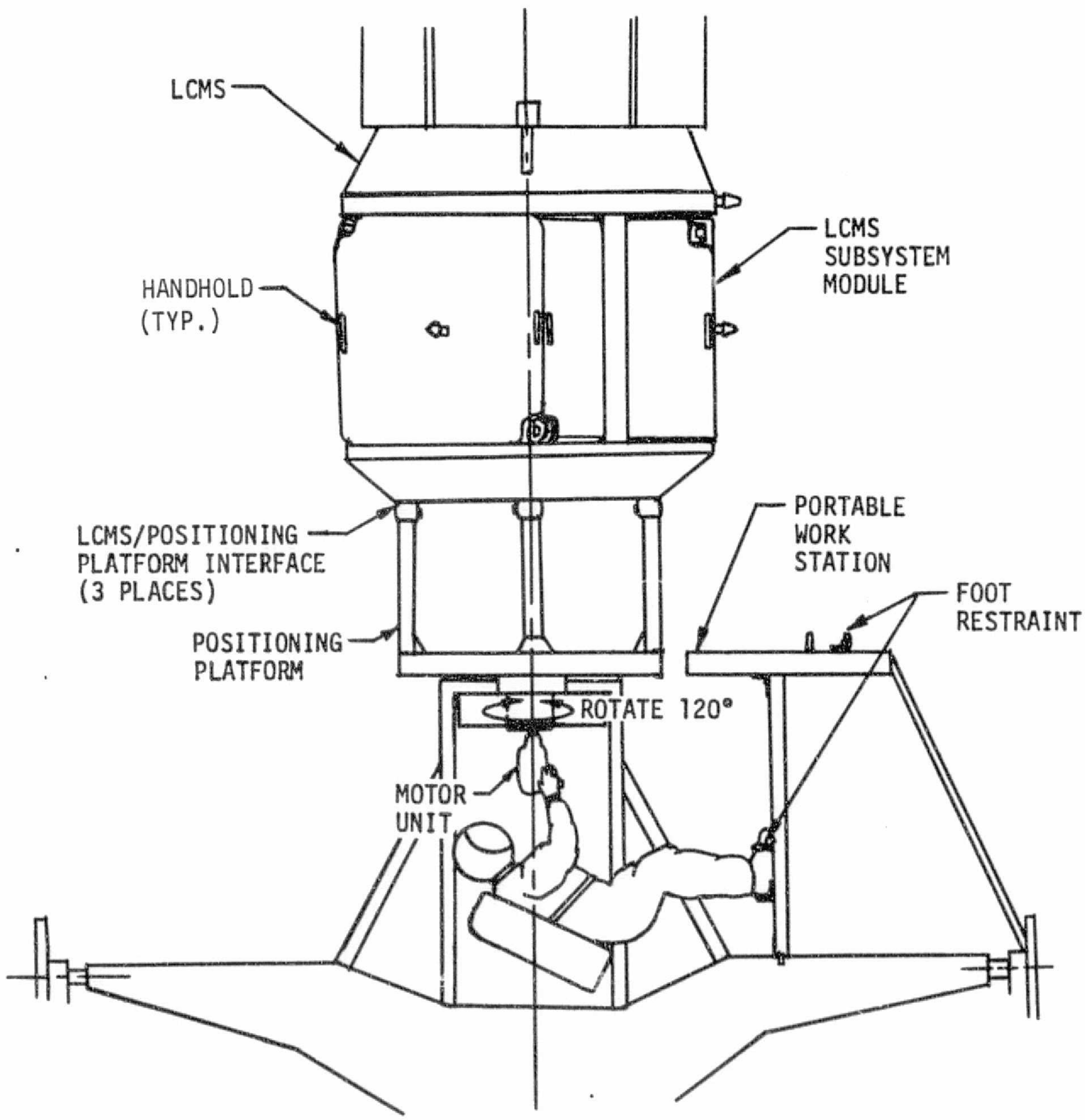


FIGURE: 2.3-32: LCMS/POSITIONING PLATFORM ROTATION FOR SUBSYSTEM MODULE ACCESS

2.4 LARGE SPACE TELESCOPE (LST)

2.4.1 LST Program Description

2.4.1.1 Introduction

The Large Space Telescope (LST) is a free-flying unmanned observatory representing an international facility for astronomy research while controlled by the investigating scientists on the ground. Analogous to other astronomy payloads using the Space Transportation System, the LST will provide the capability to conduct surveys and detailed measurements of the various energies radiated toward earth from celestial sources. The LST makes possible the further study of the structure and evolution of the universe and the laws that govern it.

The LST mission objectives are to study a diverse variety of astronomical problems by utilizing: (1) the three-to-five increase in limiting magnitudes over ground-based telescopes, (2) the capability of high angular resolution imaging, and (3) the extension of astronomical spectroscopy to wavelengths and to limiting magnitudes far beyond the capabilities of ground-based instruments. The large and dynamic instrument complement planned on LST will permit observations of planets, stars, nebulae, galactic and globular clusters, galaxies, galactic nuclei, quasars, and other yet undiscovered objects to unprecedented accuracy. Due to the proposed high quality imaging, it may be capable of supplying solutions to a large number of cosmological problems that have little hope of being solved from ground-based instruments.

The LST is the keystone astronomical instrument for the 1980's (initial launch planned for Dec. 1982) in its relationship to other astronomy discipline objectives. Survey telescopes and the one-meter ultraviolet-optical diffraction limited sortie telescope will locate unusual sources for detail observations by the LST. The LST also complements on-going ground-based observational programs and fills data voids in specific areas

of research, particularly in the ultraviolet and infrared regions of the spectrum. The observational programs will be confined to specific objects using instruments that are selected to provide data for answering questions and resolving problems that arise in the course of ground activities.

The Large Space Telescope is a 2.4-m. (7.9 ft.) diameter, near diffraction limited Ritchey-Chretien system with a high reflection efficiency in the 0.1 to 0.5 micrometer spectral region. The primary mirror is attached at three points to a supporting structure. The high quality data field at the principal focus is 5 arc-min. in diameter. The outer field of view, extending 24 arc-min. in diameter, is used for fine guidance in order to achieve pointing stability of 0.005 arc-sec. The secondary mirror is moved by actuators to compensate for errors that are below the sensitivity of the basic attitude control system. Individual pickoff mirrors and slits are arranged off of the optical axis for redirection of light into the axial and radial mounted instrument complement. The instruments are mounted so that they are readily accessible for delivery, maintenance, and replacement in orbit.

2.4.1.2 LST Mission Description

The LST will utilize the Space Shuttle for initial placement into a low earth, circular orbit at a nominal altitude of 500 km (270 nautical miles) with an inclination of 28.8 degrees. During the planned 15-year operational life, the Shuttle will also be used to perform on-orbit maintenance/servicing and/or earth return to maintain LST operating proficiency and to update the scientific instrument capability. The LST Mission Operations Center (ground control) will continuously monitor the status of the LST systems, determine failures, identify degraded systems, and determine the maintenance mode (i.e., on-orbit or earth-return) for the Shuttle LST maintenance flights which will be shared with other payloads.

The LST missions and operations flow is shown by the scenarios in Figure 2.4-1. The typical activities for the three types of missions (i.e.,

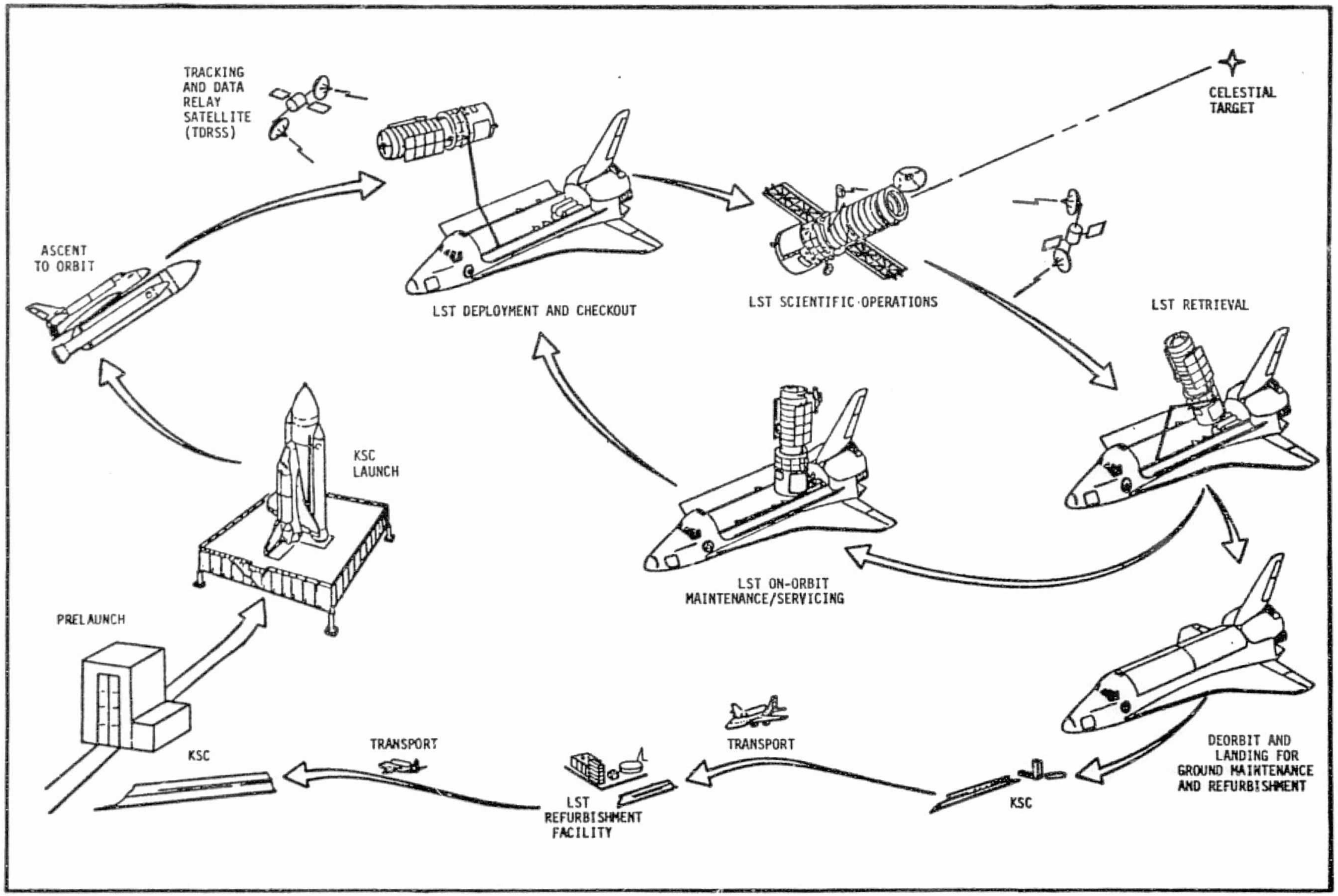


FIGURE 2.4-1: LST Mission and Operations Scenarios

placement, on-orbit maintenance and retrieval, ground return) can be summarized as follows:

PLACEMENT MISSION:

1. Prelaunch at KSC
   - LST integration and test
   - LST checkout
   - LST mated with Shuttle Orbiter
   - Space Shuttle transported to launch pad

2. Launch, Orbit Insertion, and Deployment
   - Boost and insertion into 92.7 x 278 km. (50 x 150 Nmi.) orbit
   - Shuttle External Tank dropped, orbit circularized to 150 Nmi.
   - Payload bay doors opened and Orbiter subsystems checkout performed
   - Orbiter transferred to 500 km. (270 Nmi.) circular orbit
   - LST powered-up and status verified
   - LST unlocked and erected in payload bay utilizing manipulator
   - LST pre-release checkout
     - High gain antennas and solar arrays deployed
     - Final systems verification for deployment release
   - LST deployed to final release position utilizing manipulator
   - LST released
   - Orbiter performs separation maneuver and loiters
   - LST post-release activities
     - Pointing control stabilized/subsystem checked out
     - Lock-up to TDRS/TDRS-STDN link verified
     - Solar arrays oriented for maximum power; subsystem checked out
     - Thermal control subsystem checked out
     - Aperture door opened/star trackers activated
     - Scientific instruments activated/checked and calibrated

3. LST Initiates Orbital Scientific Operations
   - Orbiter proceeds to next mission or return to Earth.

SPACE SHUTTLE EVA

ON-ORBIT MAINTENANCE MISSION:

1. Space Shuttle Launch, Orbit Insertion, and Shared Flight Operations
   - From KSC-boost and insertion into 50 x 150 NMi orbit
   - Shuttle External Tank dropped, orbit circularized to 150 NMi
   - Payload bay doors opened and Orbiter subsystems checkout performed
   - Other payload(s) mission performed
     - Assumes LST maintenance flight shared with other payload(s)
   - Orbiter transferred to LST circular orbit (Approx. 270 NMi)
2. Rendezvous/Recovery
   - LST pre-rendezvous deactivation and control
   - LST/Orbiter rendezvous
   - LST capture by Orbiter utilizing manipulator
   - LST/Orbiter erected in payload bay and hard interface established
3. LST On-orbit Maintenance/Servicing
   - Crewmen EVA preparation/EVA to LST
   - LST to Orbiter payload bay stabilization support installed
   - LST powered-down
   - LST inspection performed by EV crewmen
     - Repair/exchange systems support elements
     - Service/repair/exchange scientific instruments
   - LST verification/checkout performed following repair/exchange
   - LST to Orbiter payload bay stabilization support removed
   - EV crewmen return to Orbiter
4. Deployment
   - LST powered-up and status verified for deployment release
   - LST deployed to final release position utilizing manipulator
   - LST released
   - Orbiter performs separation maneuver and loiters

- LST post-release activities
  - Pointing control stabilized/subsystem checked out
  - Lock-up to TDRS/TDRS-STDN link verified
  - Solar arrays oriented for maximum power; subsystem checked out
  - Thermal control subsystem checked out
  - Aperture door opened/star trackers activated
  - Scientific instruments activated/checked and calibrated

5. <u>LST Initiates Orbital Scientific Operations</u>

- Orbiter proceeds to next mission or returns to earth

RETRIEVAL-GROUND RETURN MISSION:

1. <u>Space Shuttle Launch, Orbit Insertion, and Shared Flight Operations</u>

- From KSC-boost and insertion into 50 x 150 NMi orbit
- Shuttle external tank dropped, orbit circularized to 150 NMi
- Payload bay doors opened and Orbiter subsystems checkout performed
- Other payload(s) mission performed/deployed
  - Assumes LST maintenance flight shared with other payload(s)
- Orbiter transferred to LST circular orbit (approx. 270 NMi)

2. <u>Rendezvous/Recovery</u>

- LST pre-rendezvous deactivation and control
- LST/Orbiter rendezvous
- LST capture by Orbiter utilizing manipulator
- LST/Orbiter hard interface established

3. <u>Retrieval-Ground Return</u>

- LST pre-stowage deactivation performed
  - High gain antennas and solar arrays retracted
  - All systems depowered/safed (passive LST)
- LST stowed and locked in payload bay utilizing manipulator
- Orbiter reentry preparations made/payload bay doors closed
- Orbiter with LST deorbits and lands at KSC

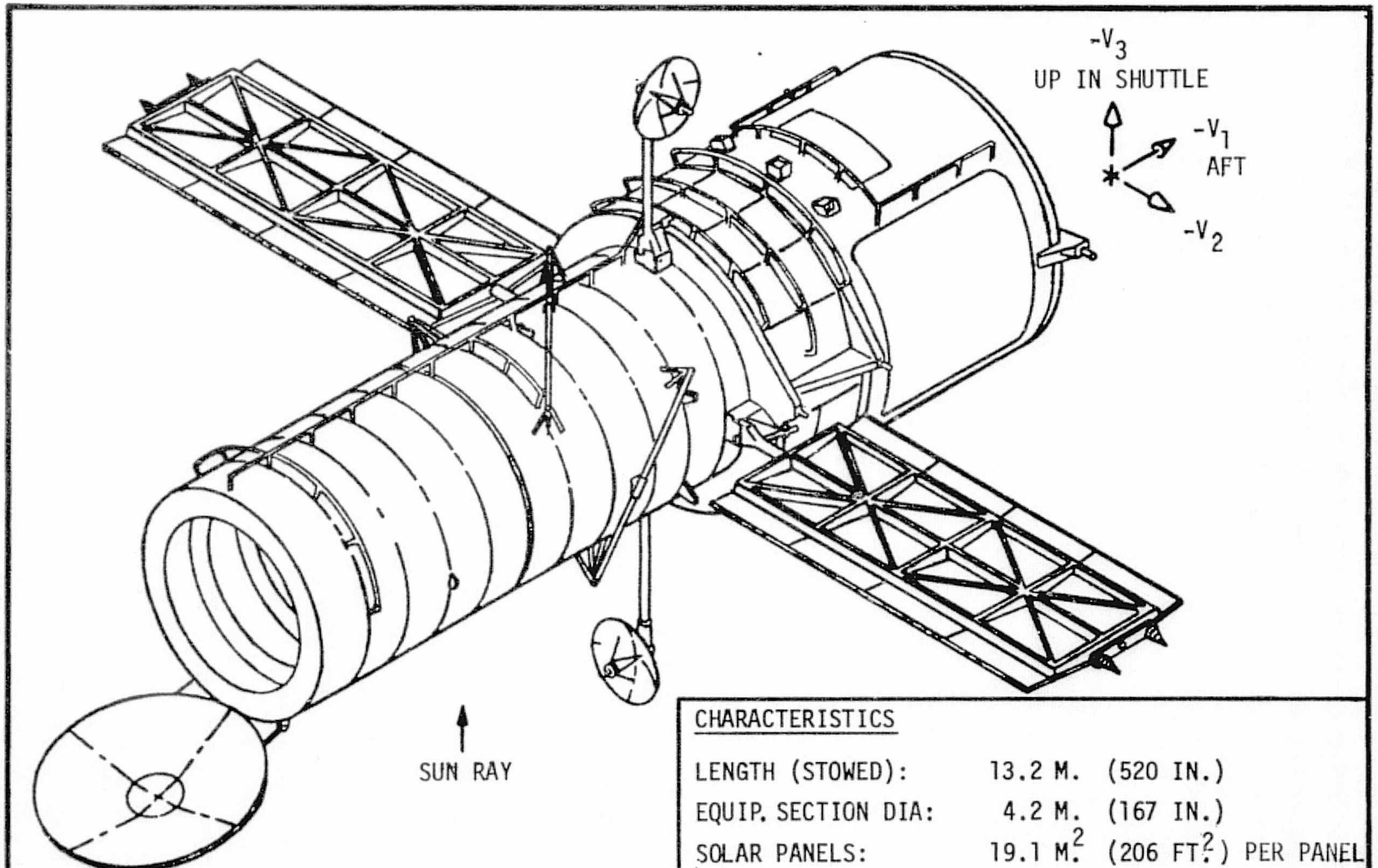
- LST removed from Orbiter payload bay
- LST transported to refurbishment facility
  - Ground maintenance/refurbishment of LST performed

2.4.1.3 LST Configuration

The design definition studies for the LST were being conducted, sponsored by the NASA Marshall Space Flight Center (MSFC) and the Goddard Space Flight Center (GSFC), in a time frame paralleling this EVA applications study. The Phase B-LST optical telescope assembly (OTA) and scientific instruments (SI) conceptual design studies were being performed by two contractors, Itek Optical System Division and Perkin-Elmer Corporation. The LST support systems module (SSM) Phase B-LST design definition studies for the total program, including preliminary design considering both OTA contractor interfaces, were being conducted by three contractors: Martin Marietta Denver Division, Lockheed Missiles and Space Company, and Boeing Aerospace Company.

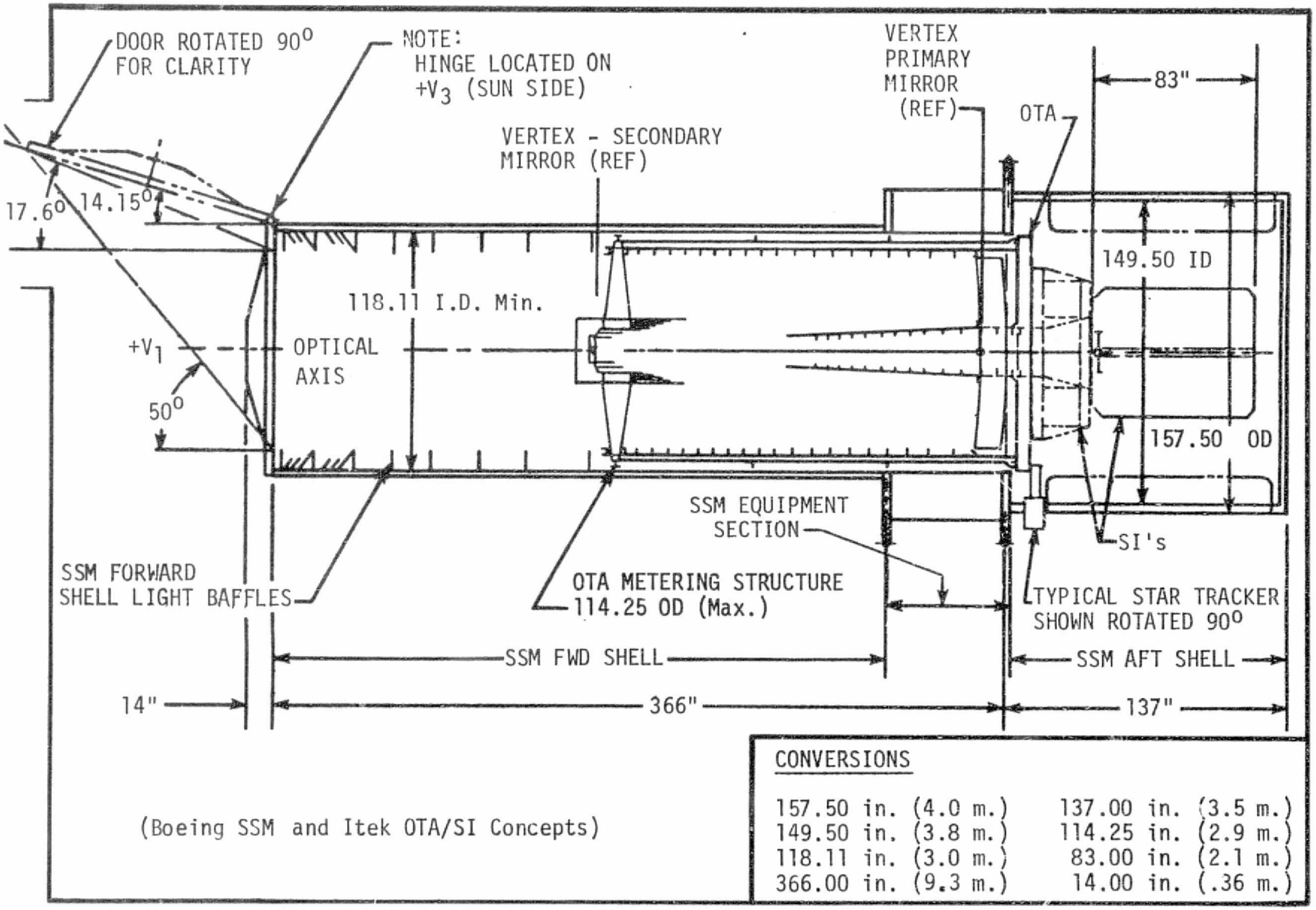
The LST configuration, including the supporting systems characteristics, final hardware configuration, and location in the Shuttle Orbiter payload bay were not available except as conceptual designs developed by each of the study contractors. Development of EVA applications for the different contractor recommended approaches to the LST design was not attempted. Since the EVA applications would be similar for the various approaches, a single contractor concept was selected for development on the basis of the overall adaptability to maintenance/repair/service of LST by utilizing EVA. Boeing/Itek LST concept, Figure 2.4-2, was selected for EVA application development.

The basic LST concept is composed of three functional elements designated as an Optical Telescope Assembly (OTA), Scientific Instruments (SI), and Support Systems Module (SSM) as shown in Figure 2.4-3. All unique equipment required to support on-orbit operations, including deployment, recovery, and maintenance is supplied as Space Support Equipment (SSE).



CHARACTERISTICS		
LENGTH (STOWED):	13.2 M.	(520 IN.)
EQUIP. SECTION DIA:	4.2 M.	(167 IN.)
SOLAR PANELS:	19.1 M^2	(206 FT^2) PER PANEL
SSM WEIGHT:	3765 KG.	(8,300 LB.)
LST WEIGHT:	7439 KG.	(16,400 LB.)

FIGURE 2.4-2: LST Configuration--Preliminary (Boeing SSM and Itek OTA/SI Concepts)



CONVERSIONS

157.50 in. (4.0 m.)	137.00 in. (3.5 m.)
149.50 in. (3.8 m.)	114.25 in. (2.9 m.)
118.11 in. (3.0 m.)	83.00 in. (2.1 m.)
366.00 in. (9.3 m.)	14.00 in. (.36 m.)

FIGURE 2.4-3: Basic LST Concept Functional Elements (SSM-OTA-SI)

The OTA consists of the optics and supporting structure; thermal, performance and fine guidance subsystems; electrical distribution, and command and telemetry subsystems (not RF transmission). Included are the following elements:

- Mirrors
- Mirror mounting and metering structure
- Fine guidance sensors
- Focal plane structure
- Optical performance sensors and control systems
- Internal light baffles
- OTA mounted electrical cabling
- Thermal controllers and heaters
- Interface structure between the OTA and the SSM.

The OTA is a 2.4-m. (effective aperture) Ritchey-Chretien form of a Cassegrainian two-mirror telescope. The primary mirror focal ratio is f/2.45 with an overall telescope system focal ratio of f/24. The unit will operate in the spectral range of 90 nm to 1 mm with a spatial resolution of 0.05 arc-second at 632.8 nm. The focal plane assembly provides the capability to support four axial SI positions and also supports the SSM rate gyros and course acquisition star trackers (Figure 2.4-4).

The SI subsystem consists of all individual scientific instruments. Selected support equipment including optics, electronics, sensors, positioning mechanisms, thermal control, self-calibration, and the structure located at the telescope focal region (which are dedicated solely to the support of scientific instrumentation) are also part of the SI's. Table 2.4.1 identifies the instruments under study for use on the LST. The primary function of the SI's is to convert the OTA focal plane energy into scientific information. The individual instruments were designed (conceptual) with the intention of modular replacement, both in orbit and on the ground. When the final selection of instrumentation for the LST is complete, the instruments will be packaged in four modules for axial mounting on the aft side of the OTA focal plane assembly. Individual instruments or support

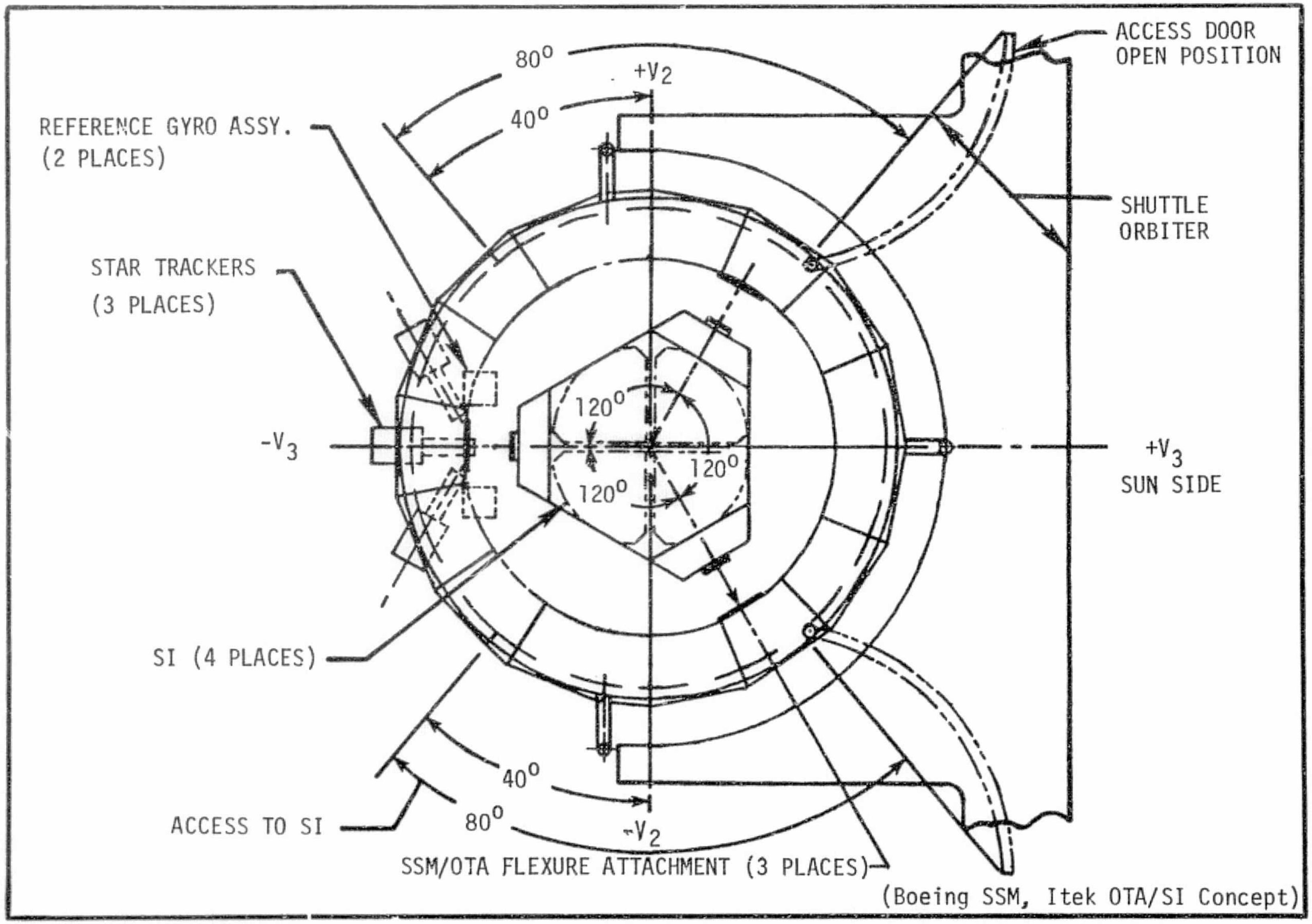


FIGURE 2.4-4: LST SSM-OTA Attachment Orientation, SSM Equipment and SI Modules on Focal Plane Assembly

TABLE 2.4.1: Science Instruments Under Study for LST

SCIENCE INSTRUMENT (Acronym)	PHYSICAL SIZE		WEIGHT	
	meter	feet	kg.	lb.
High Resolution Spectrograph (HRS)	0.815x0.875x1.700	2.674x2.871x5.578	295	650
Faint Object Spectrograph (FOS)	0.270x0.620x1.200	0.886x2.034x3.937	134	295
High Resolution Cameras (HRC)				
• F/24 Field Camera	0.300 dia. x1.050	0.984 dia. x3.445	90	198
• F/48 Planetary Camera	0.300x0.850x1.820	0.984x2.789x5.971	120	264
• F/96 Planetary Camera	0.328x0.410x2.400	1.076x1.345x7.874	160	353
High Speed Area Photometer (HSAP)	0.150x0.250x0.770	0.492x0.820x2.526	25	55
Infrared Photometer (IRP)	1.125x1.860x1.860	3.691x6.103x6.103	182	401
Astrometry Instrument (ASTRO)	Information not available			

Note: The instruments listed may not be the final choice for the LST.
Physical size and weight values are preliminary estimates.

subsystem "black boxes" will also be mounted on the focal plane structure.

The SSM consists of structural and mechanical elements including environmental control, electrical power, instrumentation and communications, data management, crew systems and pointing control subsystems. In addition to the structure for mounting and enclosing the SSM subsystems, the structural and mechanical elements include the cylindrical structure around the OTA and SI, the associated thermal control surfaces, light baffles and sun shield/ aperture door forward of the secondary mirror, meteoroid shields, and docking/berthing structure. The reference gyros and acquisition star trackers are also SSM components mounted on the OTA focal plane assembly.

2.4.1.4 LST EVA Requirements

For the LST to achieve the contemplated 15-year operational life, periodic service and maintenance will be required. Two maintenance modes, on-orbit and earth-return (see Figure 2.4-1), are being studied to determine the most cost effective combinations and frequency for the LST to retain operating proficiency and to upgrade the scientific capability. The return of the LST to the earth by the Space Shuttle has been established as the primary mode for accomplishing major refurbishment (Reference 2.4.1). The on-orbit mode will utilize EVA and consist of replacing malfunctioning and/or life-limited components, updating instruments, and visual inspections.

An LST Mission Operations Center (MOC) will be responsible for all spacecraft in-flight operational activities, including the on-orbit maintenance phase. The MOC will continously monitor LST performance and by using the on-board diagnostic capability, perform fault detection/isolation and redundancy management (from the ground) to identify failures and degraded systems. Maintenance call-up criteria will be based upon redundancy depletion and/or all SI's being inoperative. A complement of replacement hardware supplied from a ground maintenance spares inventory, with selection based on established standards and MOC status evaluation, will

be carried into orbit by a Shuttle Orbiter for in-flight EVA performed maintenance of the LST.

The LST is being designed (Phase B-Design and Program Definition) to provide the Orbiter crew with the capability for on-orbit servicing and maintenance. The requirements and guidelines established to satisfy such a design include the following (Reference 2.4.1):

- The LST shall have a capability for on-orbit servicing by space-suited astronauts, on initial launch and on a sustained basis with instrument replacement included.
- A major design goal shall be to provide EVA access to all LST components or modules.
- EVA crew aids shall be included in the LST design.
- Access to and replaceability of subassemblies within the SI's by suited astronauts shall be provided where feasible.
- The LST spacecraft envelope shall allow 48-inch clearance (1.2 m.) of the forward payload bay bulkhead for EV crewmen egress/ingress.
- All deployable appendages shall be designed for manual override capability to insure retrieval and return of the LST to earth.
- Critical systems, particularly subsystems whose failure would jeopardize recovery of the LST or affect crew safety, shall be designed to preclude single point failure. Fail safe mode of operation is required to ensure retrieval.
- The LST shall be equipped with appropriate protective devices and provisions to react to all credible LST-generated hazards including mission peculiar support equipment. Hazards associated with the LST or the deployment/retrieval procedures shall not prevent safe termination of the Shuttle mission. The LST will have specific equipment, devices, and procedures to protect the LST, Space Shuttle, and crew from hazards which may result from LST related activities.

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- Components or modules designated as replaceable in orbit shall provide connectors that permit operation by a crewman's gloved hand.
- Operations which can be performed by one crewman are preferred; however, operations requiring two may be considered.
- Diagnostic capability, as a minimum, shall include test points in all on-orbit replaceable components or modules within each system so that remote checkout from the ground can be conducted for system performance verification, malfunction detection and fault isolation in orbit.
- In designing to achieve system reliability, the priorities shall be implemented as follows:
  - Man and Vehicle Safety (i.e., the safety of the crew and vehicle during launch, EVA, and return-to-ground operations)
  - Retrieval (systems that are required to be operational in order to retrieve the LST for orbital maintenance or return to earth)
  - In-Orbit Maintenance (failure detection and system diagnosis of components which are accessible for maintenance in orbit; ability to detect that failure has occurred and ability to analyze the nature and cause of a failure)
  - Failure of observatory level systems (any module or factor that could prevent the receipt of useful data from all or the majority of SI's)
  - Failure of SI level systems (any module or factor that could prevent the receipt of useful data from a scientific instrument)

Classification of EVA tasks currently being designed into the LST during the Phase B study fall into the "planned EVA" and "unscheduled EVA" operational categories (definitions established in Section 2.1.1 of this report). The planned EVA tasks include provisions for full maintenance of all short life items externally accessible on the SSM, OTA focal plane assembly

and SI modules. The unscheduled EVA tasks are associated with LST contingency deployment and/or retrieval mechanism failures. Major subsystems of the LST payload are described in subsequent sections to identify components/modules and operations which benefit from the planned and unscheduled EVA capabilities including applications in the "contingency" and "potential planned" EVA operational categories. Design details were somewhat limited during this study since the preliminary LST design definition program was not scheduled for completion until mid-1976.

2.4.2 LST Payload Description

The conceptual design of the LST will be developed to a point in the definition phase preparatory to initiating detailed preliminary design by mid-1976. The critical design and development phase is anticipated to start in early 1977 with the selection of six contractors, one SSM, one OTA, and four SI. The LST candidate EVA applications described in subsequent sections of this report were derived from References 2.4.1 through 2.4.3 and are subject to change as development proceeds.

The LST allowable weight, including all payload chargeable support equipment, is not to exceed 25,000 lb. (11,340 kg.). This excludes weight allowances for the Shuttle Orbiter OMS (Orbital Maneuvering System) kits and propellant required to place the LST into the desired orbital location. The Orbiter payload bay length available for the LST lies between longitudinal stations 630 and 1184 which allows for an OMS tank kit length of 118 inches (3.0 m.) and EV crewmen egress/ingress cleanance of 48 inches (1.22 m.). The available payload bay dimensions [4.6 m. (180 in.) dia. by 14.1 m. (554 in.) long] must accommodate the LST spacecraft, associated space support equipment (SSE), payload support structures, deployment/retrieval mechanisms, and handling clearance.

2.4.2.1 Support Systems Module (SSM)

The LST Support Systems Module consists of three major structural sections: (1) forward shell, (2) equipment sections, and (3) aft shell. The

sections enclose and/or support the various LST equipment as shown in Figure 2.4-5. The SSM is subdivided into the following seven subsystems:

- Structures and Mechanical Subsystem (S&MS)
- Thermal Control Subsystem (TCS)
- Electrical Power Subsystem (EPS)
- Pointing Control Subsystem (PCS)
- Instrumentation and Communication Subsystem (I&CS)
- Data Management Subsystem (DMS)
- Crew Systems

Table 2.4.2 provides a preliminary listing of major equipment items comprising the subsystems, including quantities and estimated unit weights. Also included in the table is a list of the currently conceived Space Support Equipment (SSE) required to aid LST deployment, retrieval and on-orbit EVA maintenance operations. The location of equipment items accessible to the EV crewman in the SSM equipment section are shown in Figures 2.4-6 and 2.4-7, LST sun side and anti-sun side, respectively. Currently, seven of the 26 equipment bays are available as growth margin (i.e., bays 8A, 8B, 9A, 9B, 10A, 10B, and 13B are unoccupied).

2.4.2.1.1 SSM Structures and Mechanical Subsystem

The SSM structure comprises the entire outer shell of the LST with an overall length of 13.2 m. (43.3 ft.). In addition to providing the primary load bearing members, the shell provides thermal and contamination control and meteoroid protection for the OTA/SI elements of the LST. Descent and ascent venting mechanisms, sized to result in a maximum pressure differenttial of 0.15 psi, are provided in the SSM shell structure. The configuration consists of three cylindrical aluminum shell structures; forward, equipment, and aft (Figure 2.4-5).

The 3.0 m. (10 ft.) diameter forward shell is 7.7 m. (25.4 ft.) in length and subdivided into the center and fixed light shield subsections. Eight

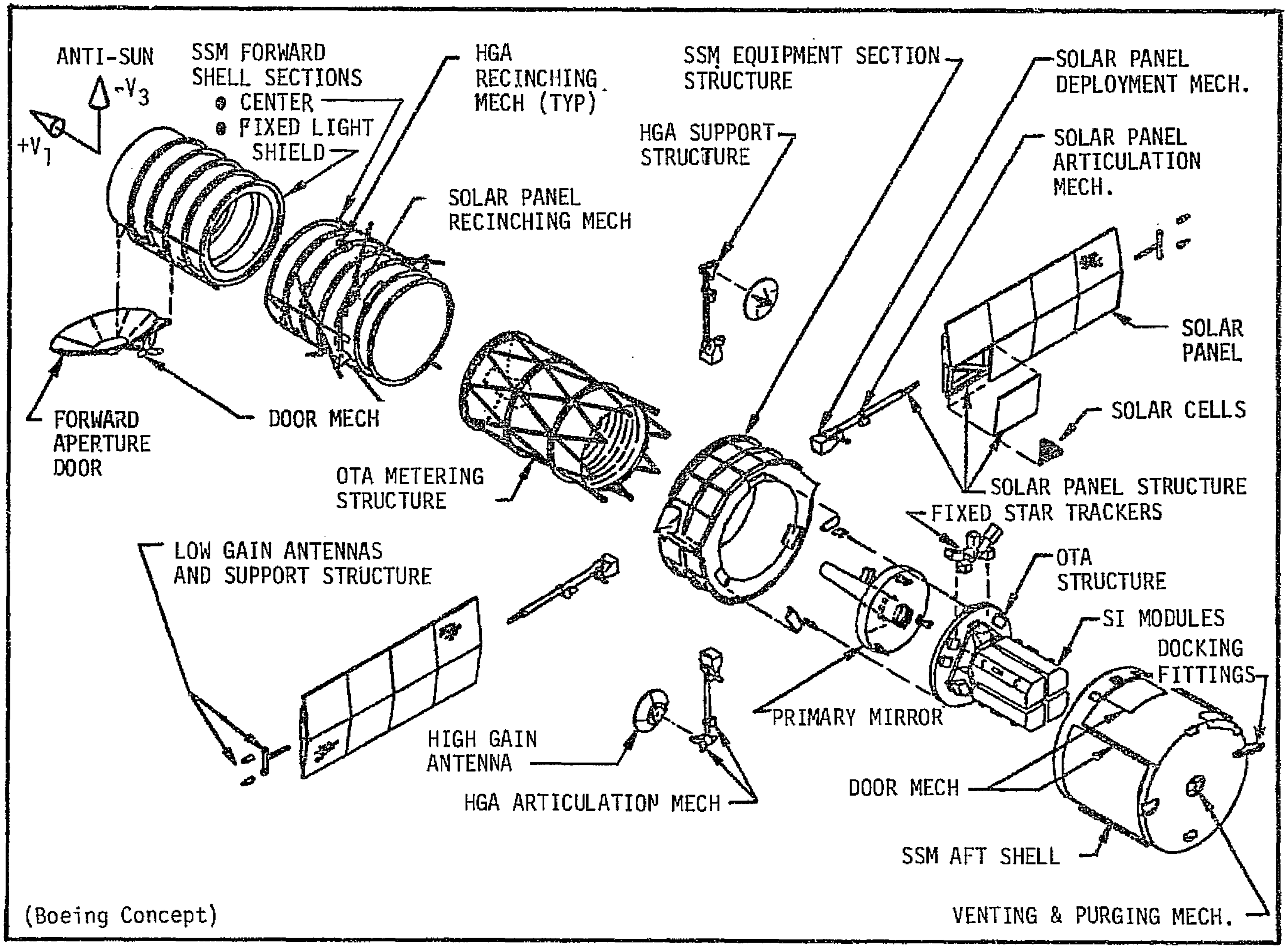


FIGURE 2.4-5: LST/SSM Configuration, Equipment Location, and Physical Characteristics

TABLE 2.4.2: LST/SSM Equipment Summary and Characteristics
(Preliminary Boeing Concept and Estimates.)

SUBSYSTEM	ASSEMBLY	Quantity Per LST	Unit Weight lb.	Unit Weight kg.
Structures And Mechanical	Solar Panel Structure	2	169	76.6
	High Gain Antenna (HGA) Support Structure	2	17	7.7
	Forward Aperture Door	1	163	73.9
	SSM Aft Shell Access Door (V2 Axis)	2	50	22.7
	SSM Aft Shell Access Door (V3 Axis)	2	25	11.3
	Docking Attachments	2	7	3.2
	Solar Panel Deployment Mechanism	2	2	0.9
	HGA Deployment Mechanism	2	2	0.9
	Forward Aperture Door Mechanism	1	19	8.6
	SSM Aft Door Mechanism	4	5	2.3
	Solar Panel Articulation Mechanism	2	9	4.1
	HGA Articulation Mechanism	2	10	4.5
	HGA Recinching Mechanism	2	14	6.4
	Solar Panel Recinching Mechanism	2	23	10.4
	Actuators	15	6	2.7
Thermal Control	Louvers (On Battery Chassis)	10	0.7	0.3
	Multilayer Insulations	1570 ft^2	0.1/ft^2	0.5/m^2
	Thermal Control Coatings (Paint)			
	- White (DC 92-007)	1365 ft^2	0.054/ft^2	0.3/m^2
	- Black (3M Black Velvet)	784 ft^2	0.022/ft^2	0.1/m^2
	Heaters	75 to 100	0.1	0.05

TABLE 2.4.2: LST/SSM Equipment Summary and Characteristics (Continued)
(Preliminary Boeing Conçept and Estimates.)

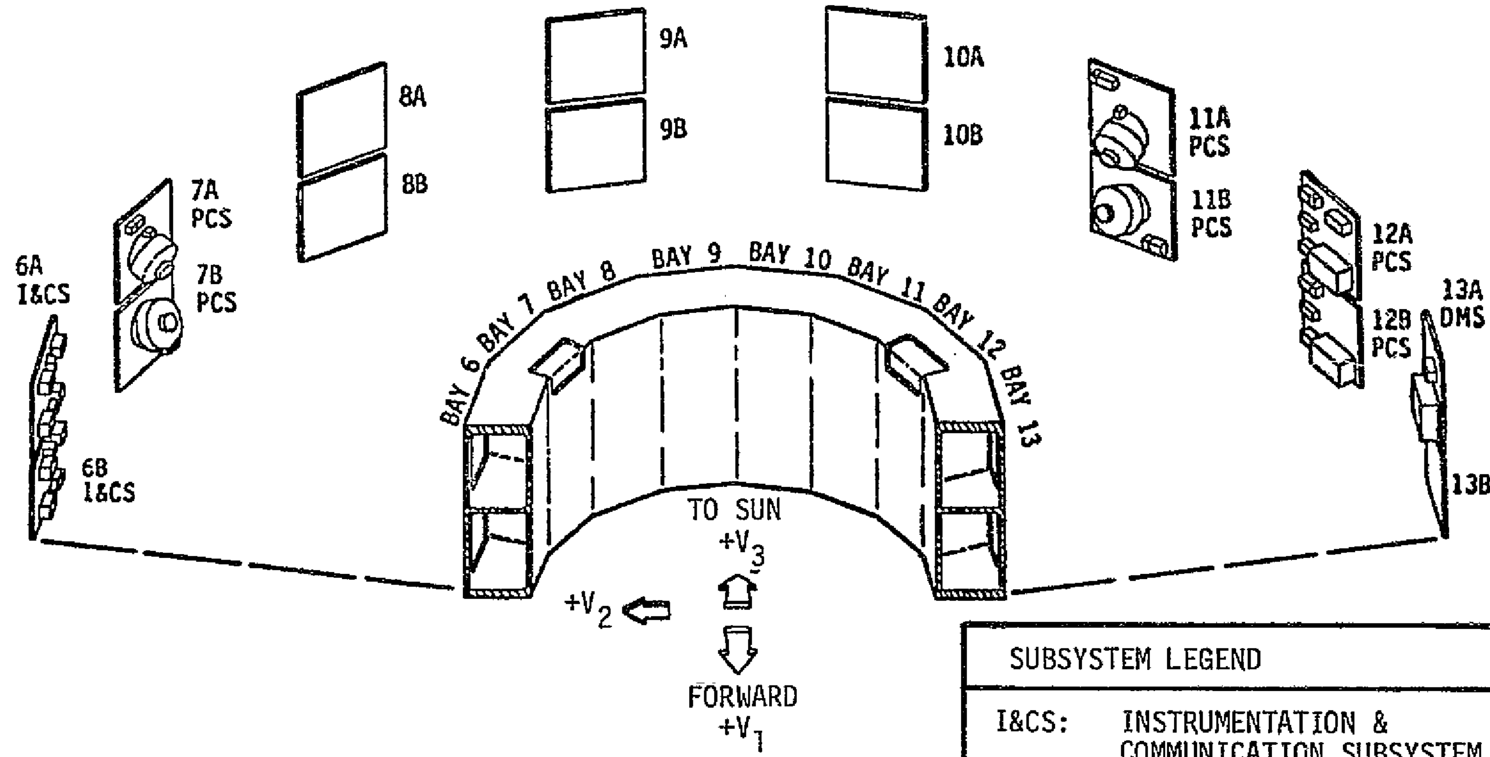
SUBSYSTEM	ASSEMBLY	Quantity Per LST	Unit Weight lb.	Unit Weight kg.
Electrical Power	Solar Panels (less structure)	2	111	50.3
	Battery (20 A-H)	10	53	24.0
	Battery Charge Controller	10	7.5	3.4
	Shunt Controller	2	2.5	1.1
	Shunt Load	8	2.25	1.0
	Power Control Unit	1	20	9.1
	Load Distribution Unit	4	2.5	1.1
	Cabling	TBD	300	136.1
Pointing Control	Reference Gyro Assembly	2	7	3.2
	Star Tracker With Bright Object Detector	3	13	5.9
	Star Tracker Shades	3	3	1.4
	Sun Sensors	2	1.3	0.6
	Magnetometer	2	2	0.9
	Reaction Wheels And Electronics	4	43	19.5
	Input/Output Assembly	2	20	9.1
	Magnet Control Electronics	2	5	2.3
	Electromagnets	4	74	33.6
	Secondary Control Electronics	1	3	1.4
	Appendage Control Assembly	2	3	1.4
	S-Band Transponder	2	10.3	4.7
	S-Band Transmitter	2	6.8	3.1

TABLE 2.4.2: LST/SSM Equipment Summary and Characteristics (Continued)
(Preliminary Boeing Concept and Estimates.)

SUBSYSTEM	ASSEMBLY	Quantity Per LST	Unit Weight lb.	Unit Weight kg.
Instrumentation And Communication	RF Power Amplifier	2	7.5	3.4
	Modulation/Demodulation Unit	2	4	1.8
	RF Switch Assembly	11	1.1	0.5
	High Gain Antenna (HGA)	2	25	11.3
	HGA RF Cable Set	2	9	4.1
	Low Gain Antenna (LGA)	4	1	0.5
	LGA RF Cable Set	4	9	4.1
Data Management	Data Aquisition			
	Central Telemetry Control	1	8	3.6
	Remote Data Aquisition Unit	12	3	1.4
	Bulk Storage Memory	1	4	1.8
	Command Control			
	Central Command Control	2	5	2.3
	Remote Command Decoder	11	1	0.5
	Command Storage Memory	2	5	2.3
	Data Storage			
	10^8 Bit Tape Recorder	3	30	13.6
	Clock			
	Oscillator	2	2	0.9
	Science Data			
	Data Control Assembly	1	5	2.3

TABLE 2.4.2: LST/SSM Equipment Summary And Characteristics (Continued)
(Preliminary Boeing Concept And Estimates.)

SUBSYSTEM	ASSEMBLY	Quantity Per LST	Unit Weight	
			lb.	kg.
Data Management (Continued)	Computer			
	Processor	2	35	15.9
Crew Systems	Handholds	20	0.5	0.2
	Fixed Foot Restraints	10	1	0.5
	Translation Handrails			
	Longitudinal	5	5	2.3
	Circumferential	7	7	3.2
	Lights (Fixed)	3	2	0.9
Space Support Equipment	LST - P/L Bay Umbilical Cable	1	Not	Available
	Caution And Warning Panel	2		
	Umbilical Disconnect/Reconnect Mechanism	2		
	Portable Foot Restraint	1		
	Equipment Transfer Rod	1		
	SI Module Guide Rod	2		
	Stabilizing Strut	1		
	Spare Equip. Rack, SSM Equipment	1		
	Spare Equip. Rack, SI Modules	1		
	Portable Lights	2		
	Cargo Bay Translation Rod	1		
	Tethers (Equipment)	6		
	Tool Kit	2		



SSM EQUIPMENT SECTION
SUN SIDE

(Boeing Concept)

SUBSYSTEM LEGEND	
I&CS:	INSTRUMENTATION & COMMUNICATION SUBSYSTEM
PCS:	POINTING CONTROL SUBSYSTEM
DMS:	DATA MANAGEMENT SUBSYSTEM

FIGURE 2.4-6: LST/SSM Equipment Location by Subsystem - Sun Side

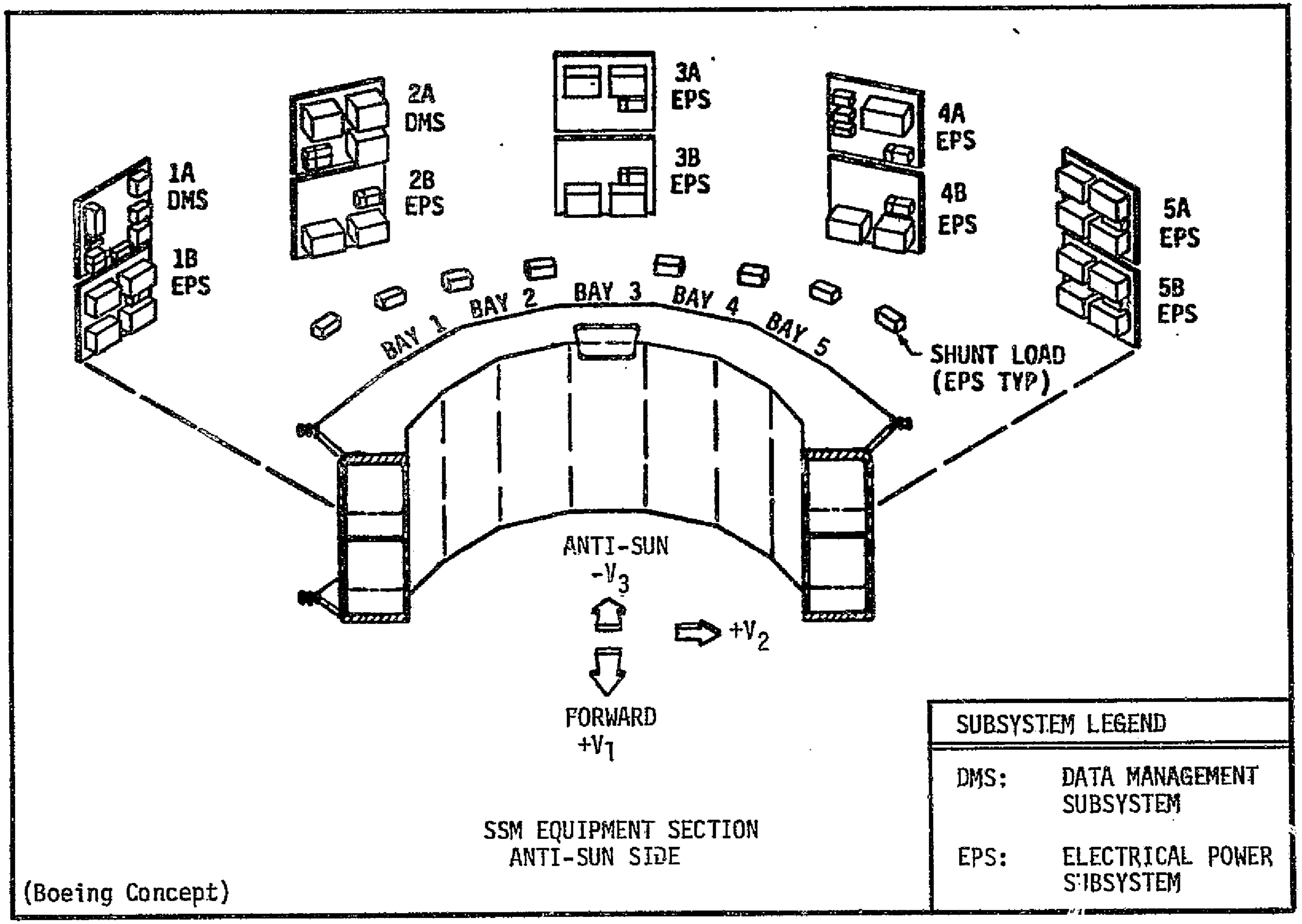


FIGURE 2.4-7: LST/SSM Equipment Location by Subsystem - Anti-Sun Side

internal light baffles (Ref. Figure 2.4-3) and smooth cylinder walls coated with high absorbent finish make up the SSM portion of the LST stray light attenuating network. The forward aperture door is closed and latched to the forward end of the light shield for optical contamination control during ground, launch, and on-orbit maintenance operations. The door also provides protection against destructive sun viewing by automatically closing when a sun presence signal is indicated by the forward mounted sun sensor (sun within 40 degrees of the +V1 axes). Two high gain antennas (HGA) and two solar panel recinching mechanisms are mounted externally on the center forward shell structure.

The equipment section, 1.5 m. (61 in.) in length and 4.2 m. (167 in.) outside diameter, has an inner shell diameter of approximately 3.0 m. (118 in.). The structure, Figure 2.4-8, incorporates four LST-to-Orbiter load retention (interface) attachment fittings and three optical telescope assembly attachment areas. Solar array and antenna appendages are mounted externally. Other crew accessible SSM equipment is mounted internally and/or on hinged chassis in 19 of 26 equipment bays. The remote manipulator interface fitting and docking target are also located on the equipment section for capture, release and control of the LST during deployment, retrieval and docking operations with the Orbiter.

The aft shell, Figure 2.4-9, is 3.5 m. (137 in.) in length with an external diameter of 4.0 m. (157.5 in.). The 3.8 m. (149 in.) internal diameter shell forms the aft closure of the LST and provides protection for the SI modules, OTA and SSM focal plane mounted equipment. Four non-structural radial doors in the shell provide crew access to the equipment. Two large doors on the V2 axis allows access to the SI's and two small doors on the V3 axis provide access to the OTA focal plane assembly. The shell incorporates star tracker ports and mounting provisions for docking acquisition and orientation lights. LST-to-Orbiter docking attachment (interface) fittings, umbilical connectors and docked stabilizing strut attachment provisions are located on the aft shell exterior.

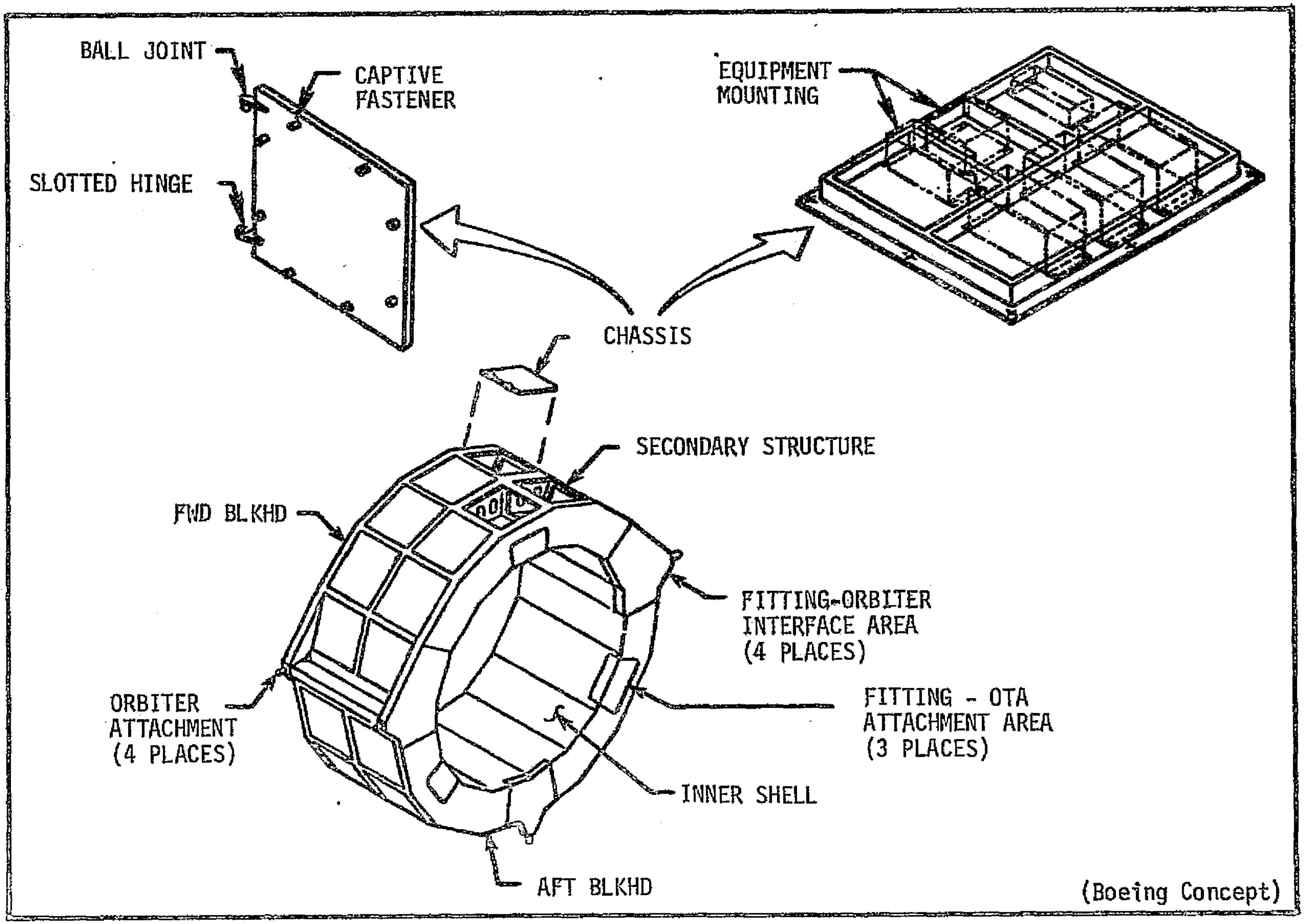


FIGURE 2.4-8: LST/SSM Equipment Section Structure Characteristics

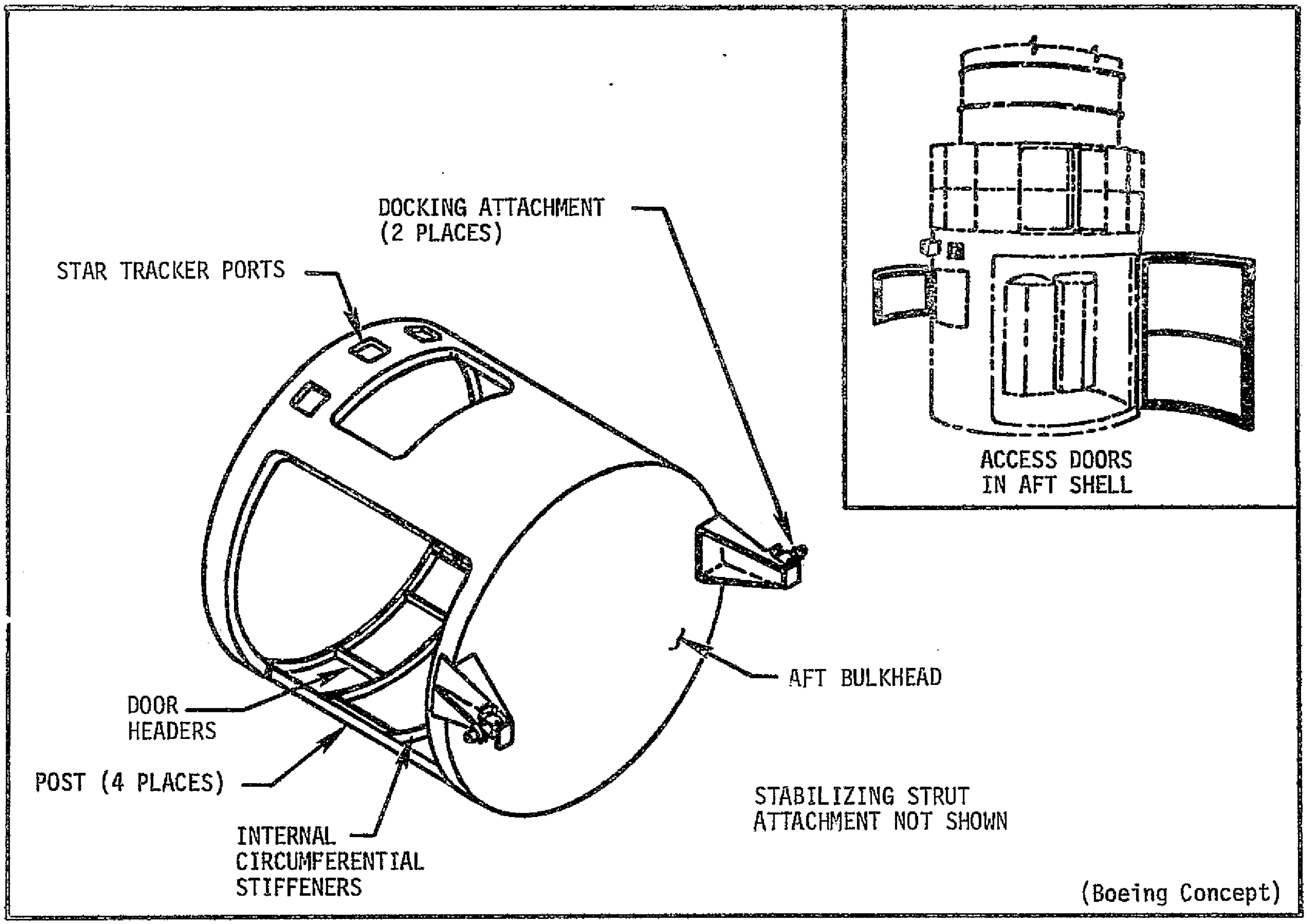


FIGURE 2.4-9: LST/SSM Aft Shell Structure Characteristics

SPACE SHUTTLE EVA

Crew accessible appendage mechanisms include the forward aperture door, solar arrays (2), and high gain antennas (2). The aperture door open/close mechanism incorporates an automatic override to ensure closure for protection of the optical systems from sun exposure. In addition to the deployment/retraction and latching mechanisms, the solar array and high gain antenna (HGA) also have articulation mechanisms. A common spur gear actuator design was tentatively selected for all mechanism applications. A total of 15 actuators (function and location identified in Figure 2.4-10) is employed on the five appendages. Manual override capability is provided in each mechanism design to allow deployment and stowage in the event of actuator failure. In the case of a jammed mechanism, EVA assisted jettison capability is being considered in the design of the solar arrays and HGA deployment/retraction booms.

The Shuttle Orbiter remote manipulator system will be used to automatically deploy and/or retrieve, dock, and berth the LST. Acquisition and orientation lights on the LST provide the crew visual trackinq aids during rendezvous and station keeping. The retrieval, docking and berthing sequence, including crew accessible equipment details, is shown in Figure 2.4-11. The deployment sequence would be the reverse of that shown in Figure 2.4-11. As noted on sheet 2 of the figure, the LST/Orbiter umbilical connection is incorporated into the left side docking mechanism. The docking concept for on-orbit maintenance (Figure 2.4-12) utilizes an EVA manually installed stabilizing strut during the maintenance period.

EVA tasks applicable to the SSM structures and mechanical subsystem have been identified in each of the four EVA operational categories described in Section 2.1.1. Installation and removal of the stabilizing strut for LST on-orbit maintenance is a planned task. Inspection, monitoring, servicing, replacement, and manual override operations of appendage mechanisms are unscheduled EVA tasks. (The initial hardware design incorporates the necessary flexibility to permit EVA operations.) Contingency functions include jettisoning appendages extending beyond the payload bay envelope and manual closing/opening of payload retention fittings. Depending on

MECHANISM/ACTUATOR FUNCTION	QTY.
1 SOLAR PANEL DEPLOYMENT & RETRACTION	2
2 SOLAR PANEL RECINCHING	2
3 SOLAR PANEL ARTICULATION	2
4 ANTENNA BOOM DEPLOYMENT & RETRACTION	2
5 ANTENNA DISH ARTICULATION	4
6 ANTENNA BOOM RECINCHING	2
7 FORWARD APERTURE DOOR ACTUATION (OPEN/CLOSE)	1
TOTAL	15

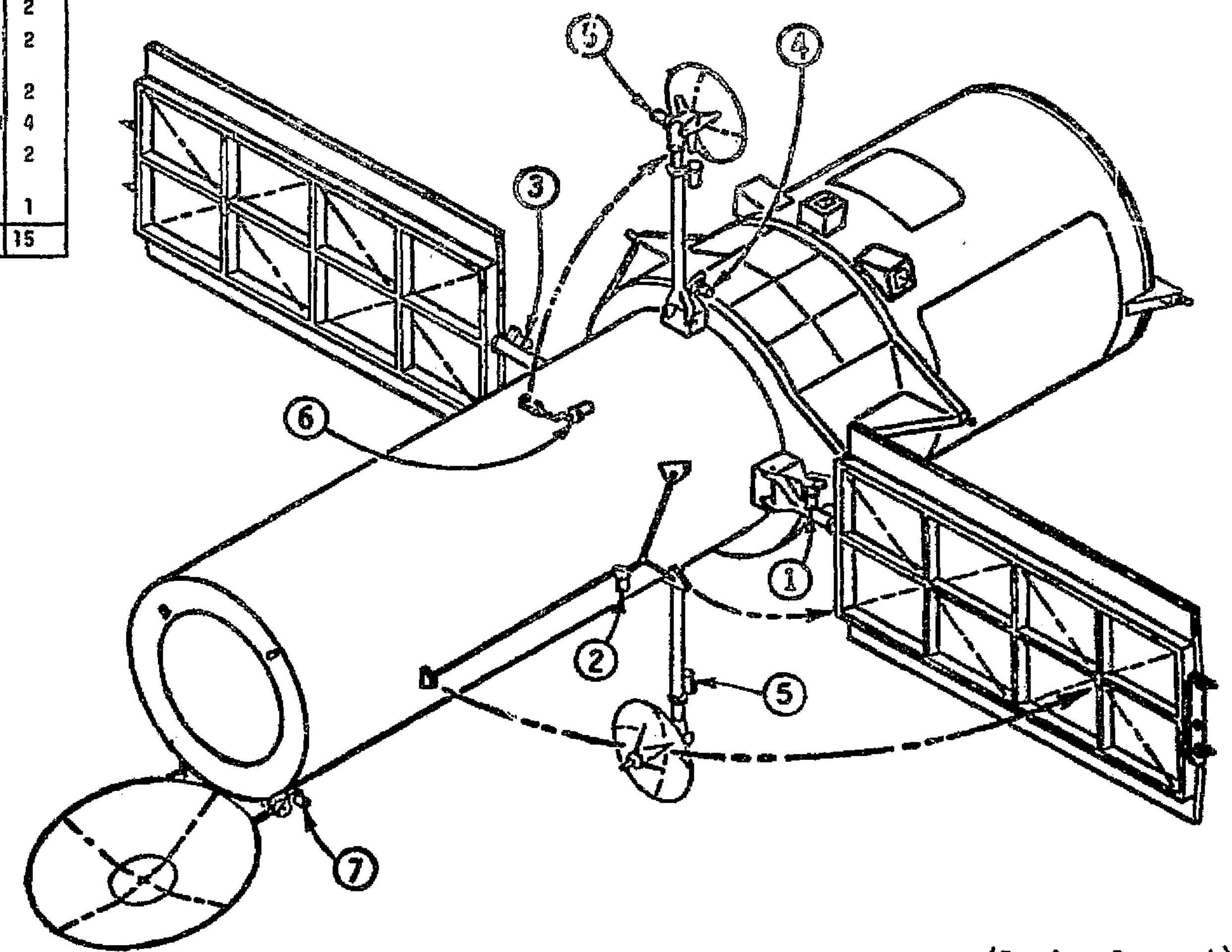


FIGURE 2.4-10: LST/SSM Functional Mechanisms Actuator Locations

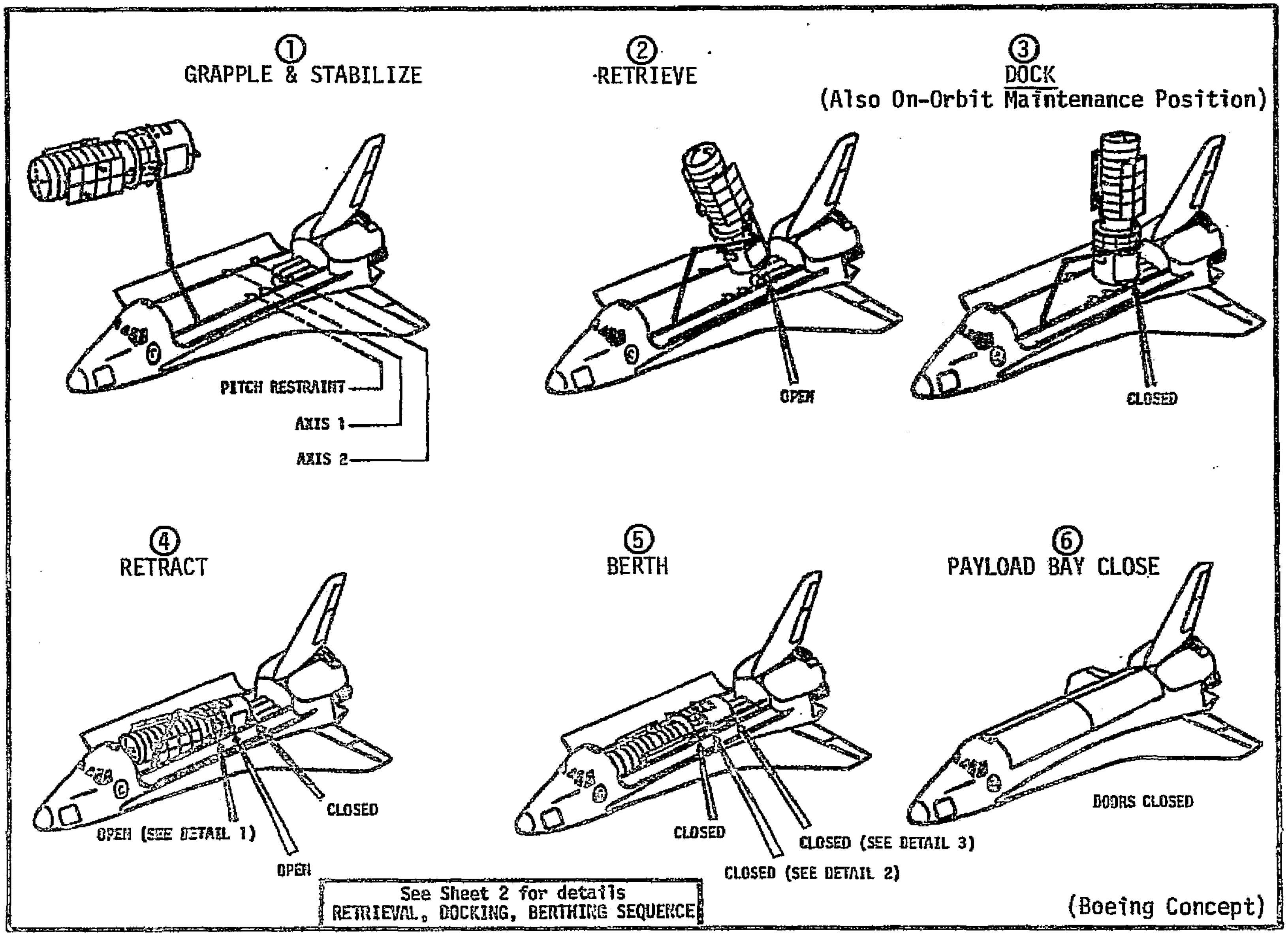


FIGURE 2.4-11: LST Retrieval/Docking/Deployment Concept

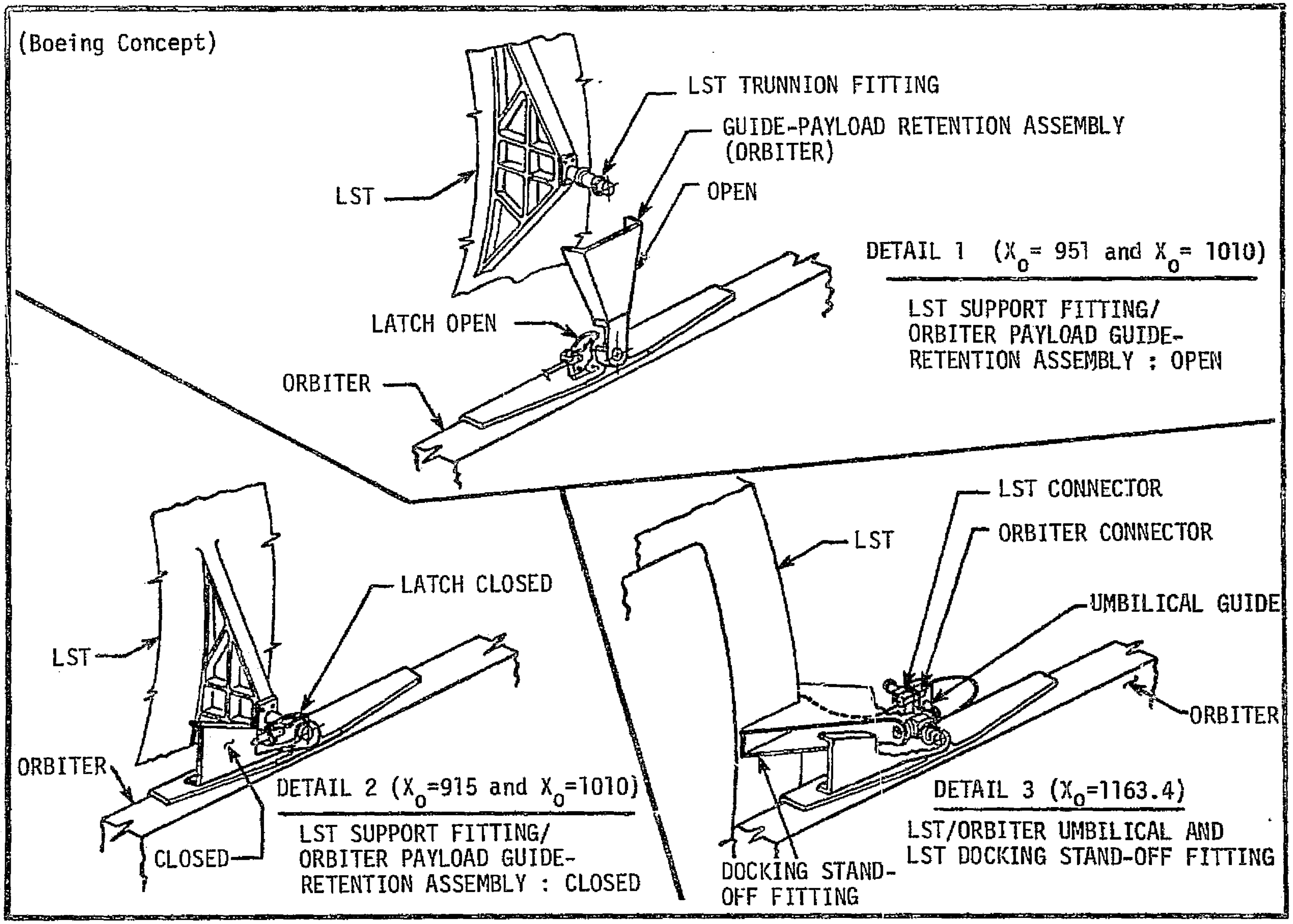


FIGURE 2.4-11: LST Retrieval/Docking/Deployment Concept (continued)

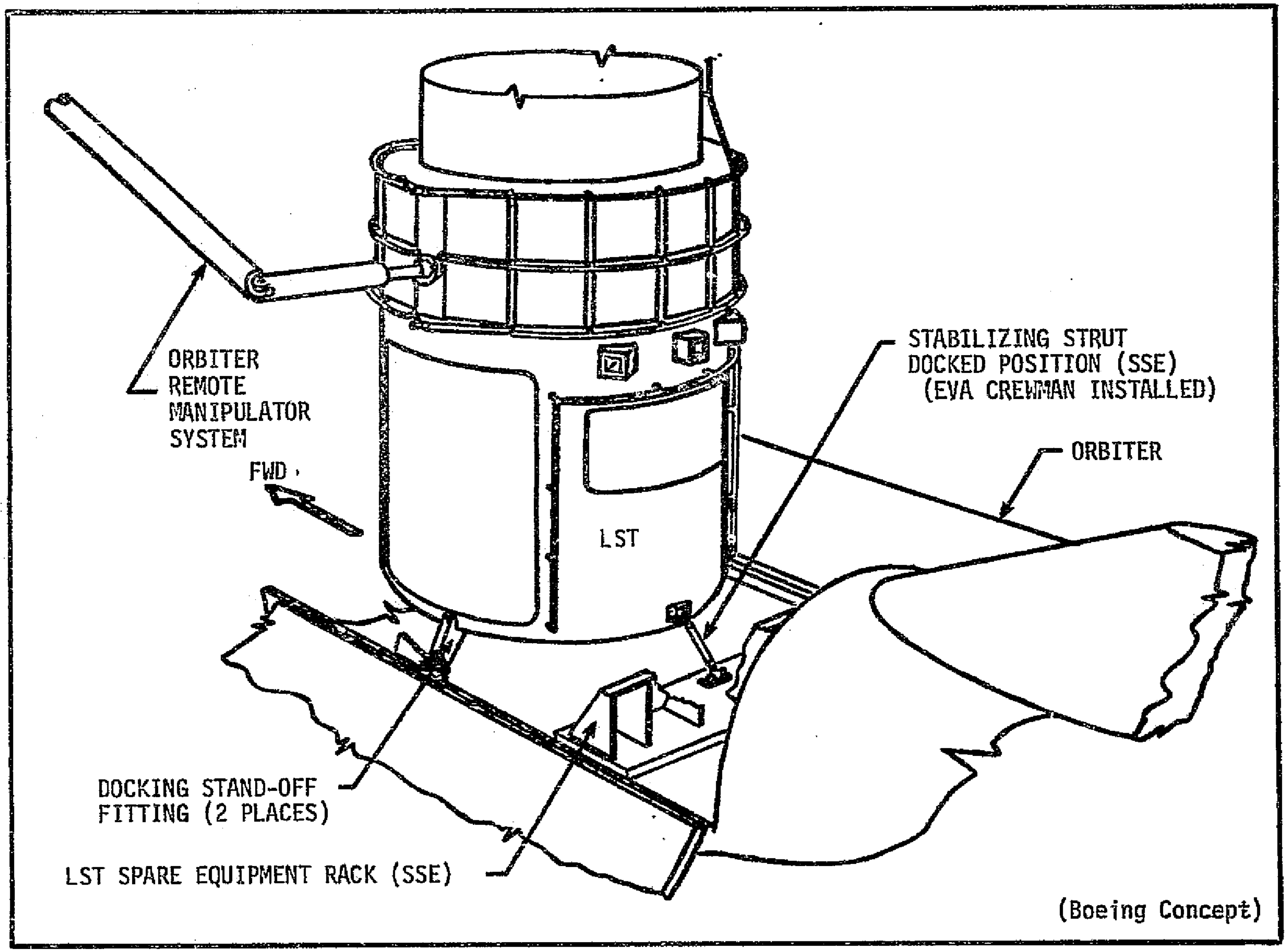


FIGURE 2.4-12: LST-Orbiter Docking Concept for On-Orbit Maintenance

the final design, replacement of the complete high gain antenna assemblies and solar array panels appear to be viable cost effective candidates for potential planned EVA tasks. Manual backup provisions to the LST/Orbiter umbilical and functional check of descent vent mechanisms are also in the potential planned EVA category.

2.4.2.1.2 <u>SSM Thermal Control Subsystem</u>

The thermal control subsystem (TCS) provides temperature control for the SSM equipment and the SSM/OTA/SI interfaces for all mission phases. The basic TCS concept uses cold biasing and thermal decoupling of the three major structural sections. The TCS equipment, Figure 2.4-13, uses cost-effective passive (coatings, insulation) and semi-passive (heaters, louvers) thermal control techniques. The multi-layered insulation (MLI) is a thermal blanket type construction build up of perforated aluminized mylar layers, nylon net spacers, dacron particle layer and aluminized beta-cloth outer and inner surfaces. Heaters (75 to 100 units) are used to compensate for cold biasing and control temperature during cold conditions. The thermal control coatings provide the cold-biased design for hot conditions.

The forward shell and aperture door use optical interior coatings and thermal control exterior coatings. In addition, the center section exterior is covered with insulation. The equipment section uses thermal control coatings with exterior MLI. As shown in Figure 2.4-14, the thermal blanket installation allows on-orbit chassis and/or equipment replacement. A combination of heaters, insulation, and thermal control coatings is used on the HGA and solar panel appendages and operational mechanisms. Louver assemblies, incorporated on each of the battery chassis, minimizes temperature transients on the batteries. An estimated 75 percent of the exterior aft shell surface, cylindrical sides and honeycomb core aft bulkhead is covered with MLI. Thermal control coatings are applied to both the interior and exterior structural surfaces of the aft shell.

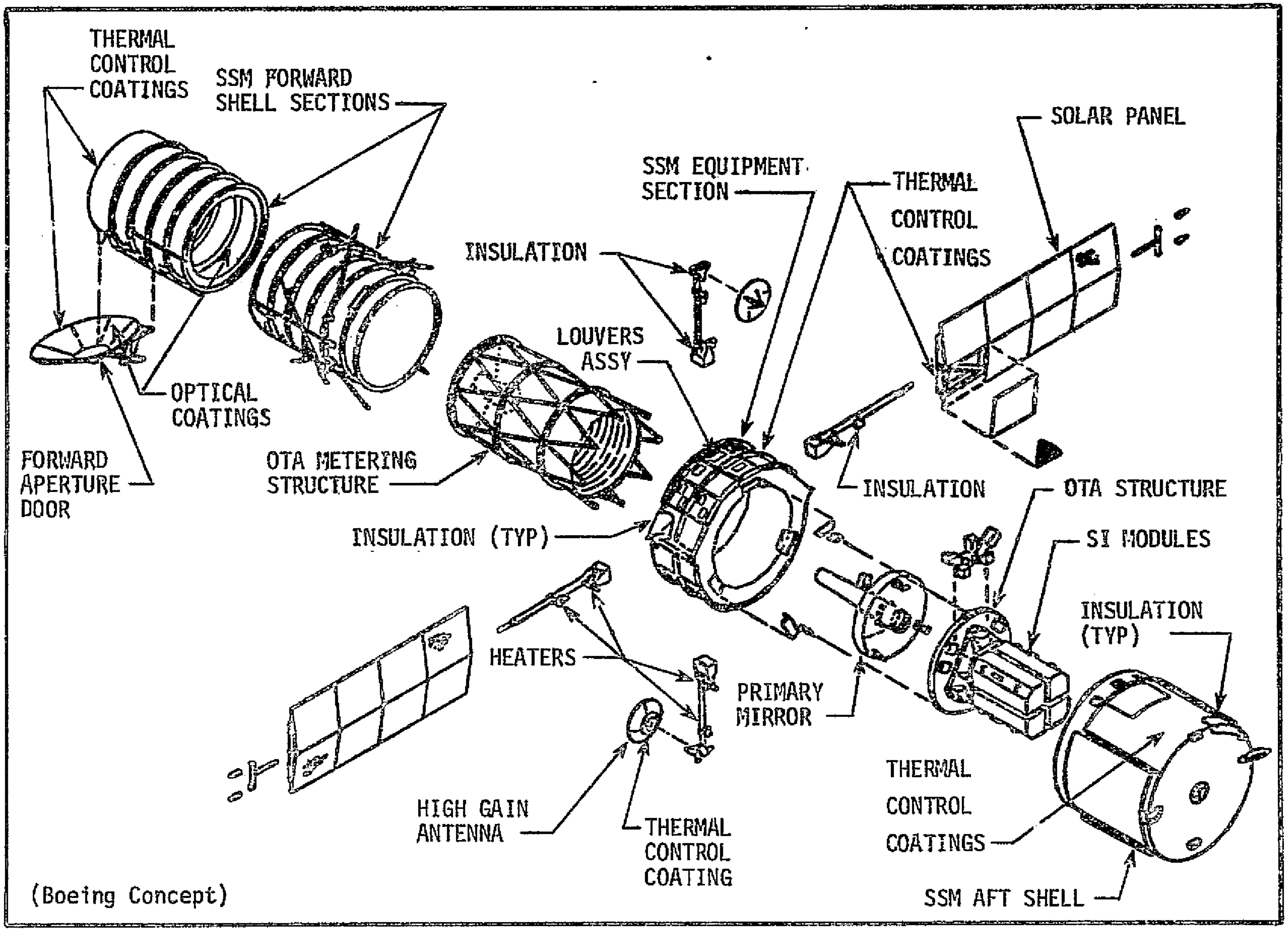


FIGURE 2.4-13: LST/SSM Thermal Control Subsystem Equipment Location

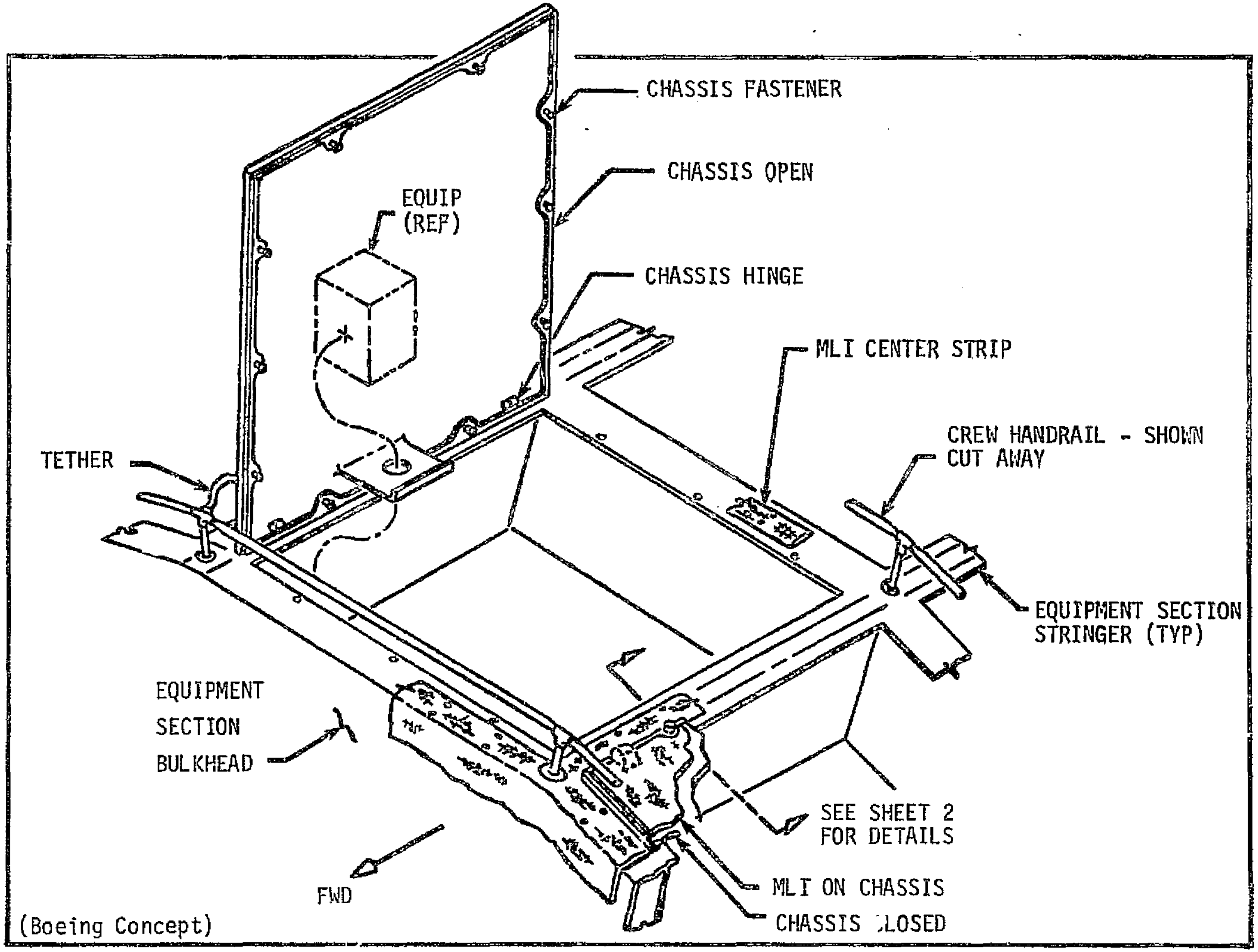


FIGURE 2.4-14: LST/SSM Equipment Chassis Replacement - Thermal Blanket Installation Concept

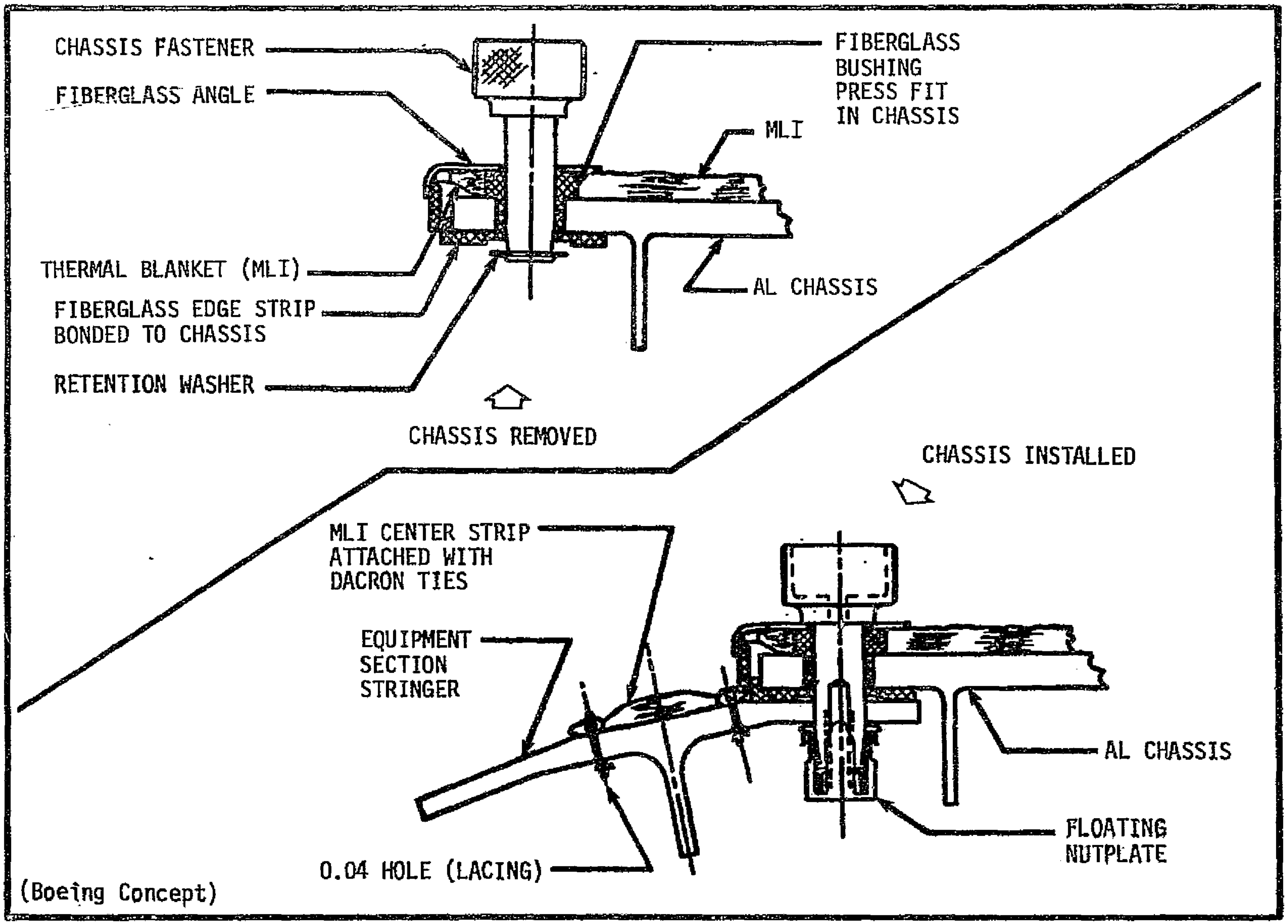


Figure 2.4-14: LST/ SSM Equipment Chassis Replacement - Thermal Blanket Installation Concept (continued)

Based upon the TCS conceptual configuration and components, all EVA tasks identified are classified in the unscheduled EVA category.

2.4.2.1.3 SSM Electrical Power Subsystem

The electrical power subsystem consists of solar arrays, rechargeable batteries, and power conditioning and distribution equipment with applicable interconnecting cabling. The 3000 watt (@ 6 year end-of-life) output solar array is of the rigid configuration type composed of two main panels (16 subpanels) which weigh 126 kg. (280 lbs.) each. Each 19.2 m^2 (206 ft^2) panel is supported on a deployable 30 cm. (12 in.) diameter boom with a 180 degree single-axis tilt capability. Command interruptable power is supplied to each SI and the OTA by the SSM single point ground system. The LST/Orbiter power umbilical (Figure 2.4-11, Sheet 2) provides power from the Orbiter fuel cell system for all the LST power requirements during launch, ascent and pre-deployment checkout. The power source is then switched to the SSM solar array and/or batteries at orbital deployment orientation. During on-orbit maintenance, power is again provided by the Orbiter after the umbilical is connected. The 24-32 VDC parallel redundant power system equipment accessible to the crew is summarized in Table 2.4.2. Thirty-five units, consisting of seven different assemblies, are either chassis or structure mounted in eight equipment bays located on the anti-sun side of the vehicle (Figure 2.4-7).

The EVA applications in the EPS are grouped in the planned and unscheduled categories. Potential planned EVA task candidates include on-orbit replacement of solar array panels (2) and electrical cables.

2.4.2.1.4 SSM Pointing Control Subsystem

The pointing control subsystem provides the LST with maneuver capability and momentum management for scientific target acquisition, fine pointing, tracking, and retrieval attitudes. The subsystem, integrated with the DMS, has the following seven modes of operation: (1) celestial hold, (2) inertial hold, (3) maneuver, (4) pointing, (5) track, (6) backup, and

(7) transportation. Four reaction wheels supply a momentum and torque capability sufficient to perform a 90 degree maneuver in 20 minutes (includes 2 minute settling time). Failure detection and redundancy management provide emergency retrieval capability via handover to the back-up magnetic (gravity gradient) control mode which can achieve capture attitude stabilization in 4 to 6 orbits. LST flight control is designed such that the maximum runaway rate is 0.1 deg/sec with a maximum torque (all axes) of approximately 1.4 N-m (1.0 ft-lb) as compared to the Shuttle RMS torque capability of 289 N-m (213 ft-lbs) in wrist roll.

Crew accessible PCS equipment is incorporated in both the SSM and OTA elements of the LST. The SSM items consist of eleven identifiable assemblies (27 total units) which are summarized in Table 2.4.2. The OTA items shell bulkhead. The SSM reference gyro assemblies [25x20x13 cm. (10x8x5 in.)], star trackers [14x15x30 cm. (5.5x6x12 in.)], and OTA items are mounted on the are located externally on the fixed light shield and center SSM forward shell sections, respectively. The magnetometers are located on the SSM aft shell bulkhead. The SSM reference gyro assemblies 25x20x13 cm. (10x8x5 in.), star trackers 14x15x30 cm. (5.5x6x12 in.), and OTA items are mounted on the OTA focal plane assembly (Ref. Figures 2.4-4 and 2.4-5) and are accessible through the V3 axis aft shell doors. The star tracker shades extend through the aft shell structure ports and interface the tracker units through a flexible bellows assembly. The remaining PCS assemblies are chassis mounted in six equipment bays on the sun side of the SSM (Ref. Figure 2.4-6).

EVA applications in the PCS are grouped into the planned and unscheduled categories and consist of component replacement based on operational life limitations and/or malfunction. No PCS EVA tasks have been identified in either the contingency or potential planned categories.

2.4.2.1.5 SSM Instrumentation and Communications Subsystem

The SSM instrumentation and communications subsystem (I&CS), when integrated with the DMS, collects and disseminates all engineering and

science data between the LST subsystems and the ground. The LST primary communications link with the ground will utilize the Tracking and Data Relay Satellite System (TDRSS). The subsystem will include the capability to use the Spacecraft Tracking and Data Network (STDN) as a supplemental or backup link. When in the Shuttle Orbiter payload bay, communications between the LST and ground will be routed through the Orbiter system. The dual redundant communications configuration will utilize the S-band radio frequencies between the TDRSS single access and multiple access antenna links which will be available to the LST 33 and 85 percent of each orbit, respectively. The subsystem will transmit realtime and delayed time playback engineering and science data from the LST and also receive realtime or time-tagged command data from the ground.

Instrumentation sensors and associated signal conditioning equipment definitions were not available during this study (early 1976). However, preliminary communications equipment accessible by the crew is summarized in Table 2.4.2. The two high gain antennas (HGA) are mounted on 13 cm. (5 in.) diameter, 2.9 m. (113 in.) long deployable booms located on the $\pm$V3 axes of the equipment section (Ref. Figure 2.4-5). Each one-meter diameter parabolic disk HGA is steerable, with simultaneous dish and boom motion, and allows maximum data coverage via TDRSS. The low gain antenna (LGA) configuration consists of two receive and transmit units which provide isolation for the command receive, high power transmit, and S-band single access transmit frequencies. A pair of LGA's is mounted on support structures located at the end of each solar panel boom (Ref. Figure 2.4-5). The remaining I&CS equipment is located in two bays, 6A and 6B, on the sun side of the SSM equipment section (Ref. Figure 2.4-6).

The I&CS "back-box" equipment is generally being designed to be serviced or replaced by using planned or unscheduled EVA operational modes. Antenna replacement is a candidate for potential planned EVA tasks. With the exception of jettisoning the HGA parabolic dishes (if not manually positionable for LST recovery), no contingency EVA operations have been identified for the I&CS.

2.4.2.1.6 SSM Data Management Subsystem

The data management subsystem is merged with the I&CS for interfacing other vehicle subsystems, thereby allowing the LST the capability to function in a real time or stored command mode. The subsystem provides data acquisition and storage, command control, timing, and the computing functions related to the SSM, OTA, and SI engineering housekeeping and scientific operations. The preliminary DMS baseline design concept uses a decentralized approach and consists of an SSM computer and data handling subsystem, SI mini computers, SI sequencers, and buffer memories. The data acquisition and command control requirements are satisfied by using bi-directional partyline equipment interfaced with the computer.

The SSM/DMS equipment assemblies accessible to the crew are summarized in Table 2.4.2 and comprise 10 different units. An estimated 37 assemblies are located primarily in three SSM equipment section bays (Ref. Figures 2.4-6 and 2.4-7) and one or more remote units on fourteen chasses. In addition, it is proposed that the SSM furnish an estimated 26 remote units (6-data acquisition, 20-command decoder) to the OTA and SI elements for mounting on the focal plane structure.

The DMS consists of all "black box" components which are designed for internal vehicle mounting. Therefore, planned or unscheduled EVA can be conducted to service equipment units which are operationally life-limited and/or malfunctioning. No contingency EVA requirements were identified relative to the DMS.

2.4.2.1.7 SSM Crew Systems

The LST crew systems equipment (man-machine) interfaces with all other SSM subsystems to assure that EVA orbital maintenance capability is incorporated into the hardware design. Within the scope of the maintenance capability definition, equipment packaging and layout are optimized and EVA support equipment provided to maximize crew efficiency and safety. The crew aids include fixed and portable translation, restraint, and lighting equipment

as summarized in Table 2.4.2 under crew systems and space support equipment (SSE). The summary also includes equipment transfer devices for handling replacement hardware items. The storage and restraint for the portable crew aids, tools, and equipment spares are provided by spare equipment racks to be over the OMS tank kit(s). It should be noted that additional lighting may be required at the aft end of the payload bay to provide adequate illumination of the LST anti-sun side. Preliminary crew systems and space support equipment concepts for LST on-orbit maintenance are depicted in Figure 2.4-15. Translation handrails, handholds, foot restraints (fixed or portable) and tether attach points are provided for access to all work-sites on the exterior shell and the internal aft shell of the LST. Final configuration of crew systems EVA support equipment will not be defined until the vehicle hardware design and maintenance capability required are firmly established.

2.4.2.2 Optical Telescope Assembly/Scientific Instruments (OTA/SI)

The 2767 kg. (6100 lb.) optical telescope assembly (OTA) is housed within the SSM outer shell structure (Ref. Figure 2.4-3) and supported through three-120 degree radially spaced flexure attachments (Ref. Figure 2.4-4). The flexure attachments interface at the SSM equipment section aft bulk-head (Ref. Figure 2.4-8) and OTA focal plane assembly structure. The adjustable two-mirror system is mounted within a 2.9 m. (114.3 in.) diameter metering structure supported from the forward face of the focal plane assembly. Four axially mounted scientific instrument modules, supported from the aft side of the focal plane assembly, contain the various instrument (Ref. Table 2.4.1) systems. Each SI module, approx-imately .76 m. (30 in.) square by 2.1 m. (83 in.) in length is limited to 340 kg. (750 lbs.) maximum weight or 907 kg. (2000 lbs.) for the four units. Additional scientific instruments and/or support subsystem black boxes are mounted on the focal plane assembly structure along with the OTA associated sensors, electronics, SSM star trackers and reference gyros. Optical contamination monitor gages located near sensitive areas (i.e., optics, SI slits, light baffles) will be used to qualify data reduction. The equipment items located on the focal plane assembly are

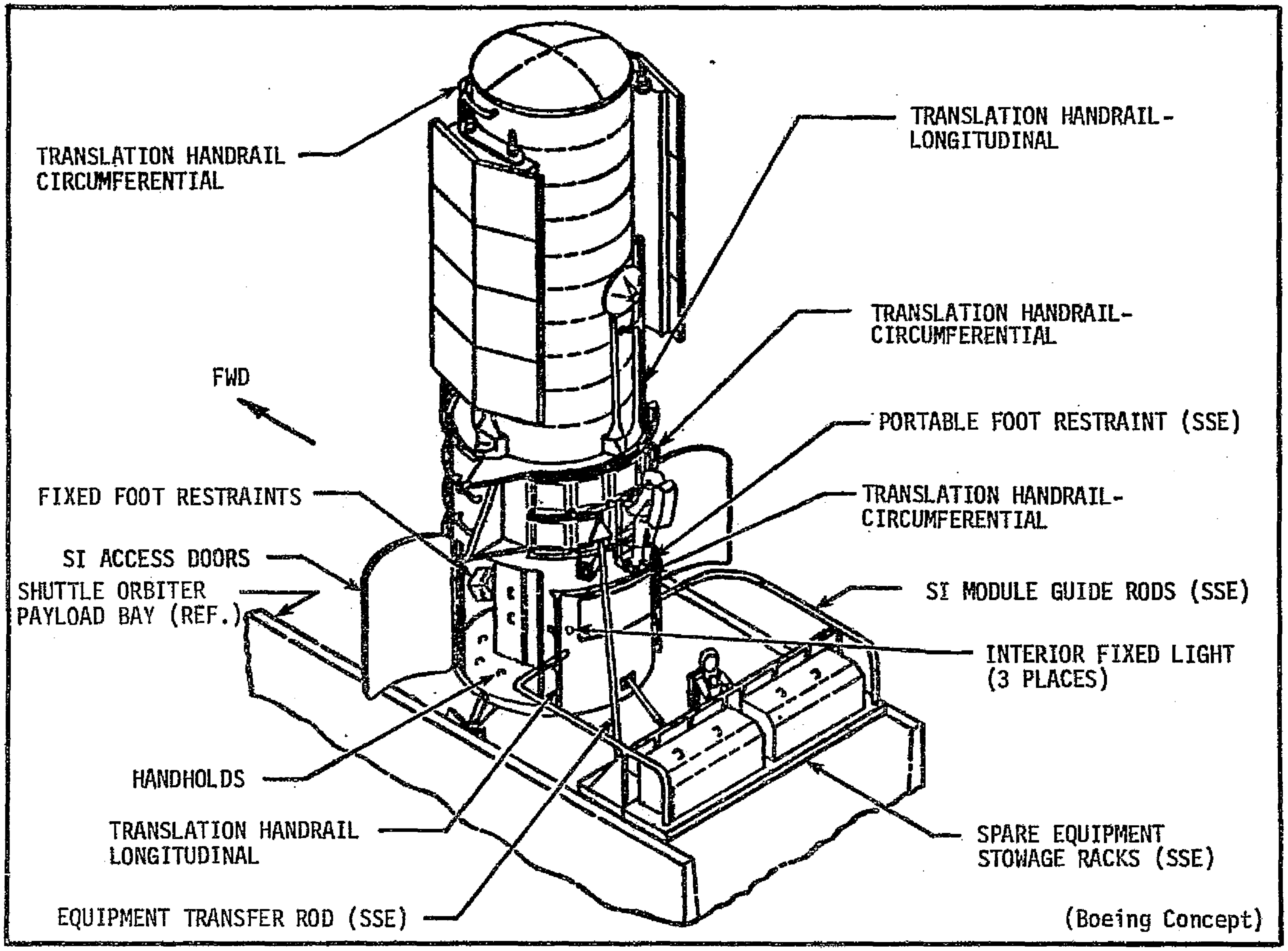


FIGURE 2.4-15: SSM Crew Systems and Space Support Equipment Concepts for On-Orbit Maintenance

arranged to allow the removal of individual units on-orbit. Self-alignment devices and insertion guides will be provided for replacing instruments to minimize the need for excessive EVA crewmen dexterity and specialized maintenance skills. The precision design and critical alignment requirements imposed upon the internal assemblies of the OTA and scientific instruments/ modules preclude the need for on-orbit EVA interior access. Because of the potential contamination deposition on OTA/SI sensitive areas and the resultant affect on data quality, no EVA tasks are currently planned relative to the SSM forward shell or OTA metering structure interior. However, EVA inspection, cleaning and monitor replacement tasks have been identified in the potential planned category (assuming changes would be made to reduce EMU generated contamination products within acceptable limits). The IR instrument will use two-stage cryogenic cooling for the detectors. The present design requirement (Ref. 2.4.1) is to supply cooling of the detectors for a minimum duration of 12 months. A cost effective potential planned EVA may be applicable to reservice the cryogenic fluid dewars rather than instrument change out. The on-orbit LST maintenance capability will include full service and replacement of all life limited OTA/SI equipment units mounted on the focal plane assembly, taking advantage of both the planned and unscheduled EVA modes.

2.4.3 LST EVA Task Description

2.4.3.1 LST Planned and Unscheduled EVA

The LST preliminary design and program definition studies have included investigation of on-orbit maintenance as a viable means of reducing initial as well as life-cycle costs. The project requirements and guidelines specify that capability for on-orbit service and maintenance by suited crewmen, both on initial launch and on a sustained basis, be designed into the LST. Preliminary contractor (Boeing) maintenance analysis has further defined the capability to provide the following:

- Full scheduled and unscheduled planned maintenance of expected wearout items accessible externally on the SSM and on the focal plane assembly including the SI modules
- Contingency (unscheduled) maintenance for deployment or retrieval failures (i.e., provide manual override).

This capability coincides with the planned and unscheduled EVA operational categories as defined in Section 2.1.1 by this study. Planning beyond the above contractor defined EVA capability discloses additional equipment items in which EVA can be employed to return a subsystem to operational status. From an analysis of available LST information EVA tasks were identified and classified as planned or unscheduled EVA and are listed in Table 2.4.3 by vehicle element. The unaided EVA operational mode provided by the Shuttle Orbiter was selected to support the task functions. Other applicable EVA operational modes which could be adapted to complete the identified tasks are EVA on RMS and EVA with MMU.

2.4.3.2 LST Contingency EVA

Contingency EVA is a viable approach to correcting LST problems on-orbit. Analysis discloses that payload associated problems involving systems which extend beyond the payload bay envelope may require EVA to implement corrective action for safe Orbiter return. Contingency EVA tasks based on postulated anomolies are identified in Table 2.4.3. EVA would be used to perform corrective actions or override the subsystems to retract the hardware. EVA appears highly applicable as a backup to auto deployment/ retraction systems for the LST since the solar array panels and high gain antenna booms are deployed once at mission initiation and are retracted at mission termination. Assuming a second order failure, a malfunction of the override mechanism would necessiate a contingency EVA to jettison the systems and enable payload bay door closure to ensure safe crew and Orbiter return. The unaided EVA mode was selected to support the task functions in the contingency EVA category; however, the EVA with MMU operational mode would also be applicable.

TABLE 2.4.3: LST EVA Task Identification

PLANNED EVA	UNSCHEDULED EVA	CONTINGENCY EVA	POTENTIAL PLANNED EVA
SSM • Service/replace all chassis mounted equipment located in Equipment Section: (Ref. Table 2.4.2, Figures 2.4-6, and 2.4-7.) - 19 Chasses-Estimate 110 potential items in EPS, PCS, I&CS and DMS. • Manual installation/removal - LST docked stabilizing Strut (During on-orbit maintenance) OTA/SI • Service/replace all equipment mounted on Focal Plane Assembly: - SSM Fixed Star Tracker (3) - SSM Reference Gyro (3) - OTA Fine Guidance Sensor (3) - OTA Figure/Focus Sensors (3) - OTA Electronics (TBD) - Science Instruments (TBD) - SI Modules (4) • Calibrate detectors and science instruments	SSM Fwd Aperture Door & Mechanism • Inspect/monitor-open/close operations • Manually close/lock door • Service/replace actuator • Unjam/repair/replace mechanism High Gain Antenna & Mechanisms (2) • Inspect/monitor-deploy/retract, recinch, and articulation operations • Manually uncinch/recinch booms • Manually deploy/retract booms • Service/replace actuators (8) • Unjam/repair/replace mechanisms (8) • Repair RF cable sets (2) Solar Array Panel & Mechanisms (2) • Inspect/monitor-deploy/retract, recinch, and articulation operations • Manually uncinch/recinch booms • Manually deploy/retract booms • Service/replace actuators (6)	SSM Deployed Appendages Extending Beyond Payload Bay Envelope (Ground Return Flight) • Fwd Aperture Door - Manually retract/lock - Jettison door clear of Orbiter • High Gain Antenna Assy. (2) - Manually retract/recinch - Jettison boom clear of Orbiter • Solar Array Panel Assy. (2) - Manually retract/recinch - Jettison boom clear of Orbiter	SSM • Replace (EVA With RMS) - Fwd Aperture Door - High Gain Antenna Assy (2) (dish, boom, & RF cable set) - Solar Array Panel Assy (2) (boom, subpanels, electrical cable) • Replace - Low Gain Antenna (4) - RF Cables (4) - SSM electrical cables • Manually connect/disconnect - LST/Orbiter Umbilical (backup to automatic system) • Functional Check/Service - Descent vent mechanisms (Prior to ground return) • Manually open/close - Orbiter/LST payload interface retention mechanism (6) (1) Initial launch (2) On-orbit maintenance flt. (3) Ground return flight OTA/SI • Replace - Optical Contamination Monitor Gages

TABLE 2.4.3: LST EVA Task Identification (Continued)

PLANNED EVA	UNSCHEDULED EVA	CONTINGENCY EVA	POTENTIAL PLANNED EVA
	• Unjam/repair/replace mechanisms (6) • Repair electrical cables (2) Low Gain Antenna (4) • Inspect/adjust • Repair RF cable sets (2) Thermal Control Subsystem • Inspect/repair/replace - Louvers-battery chassis (10) - Multilayer insulations (1570 ft^2) - Thermal coatings (2150 ft^2) - Heaters (75 to 100 units) Aft Shell Access Doors (4) • Inspect/repair/replace - Contamination/light seals • Inspect/repair/align - Hinges - Latch mechanisms Sun Sensors • Inspect • Align/replace Fixed Star Tracker Shades • Inspect • Repair/replace		• Service - IR Instrument Detectors Cryogenic Cooling Dewars • Inspect/clean - Optical Sensitive Surfaces (1) Light shield baffles (2) Primary and Secondary Mirrors (3) SI slits LST • Deploy/retrieve/berth-EVA With MMU - LST Payload (Backup to RMS)

TABLE 2.4.3: LST EVA Task Identification (Continued)

PLANNED EVA	UNSCHEDULED EVA	CONTINGENCY EVA	POTENTIAL PLANNED EVA
	<u>Electrical Cables</u> • Inspect • Repair <u>Docking Target</u> • Realign • Replace <u>Lights</u> • Replace/align - Fixed EVA inside aft shell (3) - Docking acquisition - Running orientation <u>LST/Orbiter Umbilical</u> • Inspect • Repair/align mechanism <u>Orbiter/LST Payload Interface Retention Mechanism (6)</u> • Inspect • Repair jammed mechanism • Straighten /align trunnion guides • Replace actuator <u>SSM/OTA/SI</u> • All EVA tasks identified in the "Planned" category (in the event of unexceptable performance or failure of equipment items)		

2.4.3.3 LST Potential Planned EVA

An analysis of the LST, Orbiter and EVA support equipment has revealed a number of hardware design changes and/or flight planning alternatives which would permit advantageous use of EVA capabilities. For purpose of this study, the candidate EVA activities associated with such changes are classified in the potential planned category (as defined in Section 2.1.1) and are listed in Table 2.4.3.

The on-orbit servicing/replacement of additional SSM equipment (i.e., in addition to currently planned EVA operations), including complete deployable appendage assemblies, using EVA and the RMS should be studied by LST designers. Considerations should be given to providing EVA manual backup capability in the design of such automated systems as the LST/Orbiter umbilical equipment and payload interface retention mechanisms in order to enhance overall LST mission success. Due to the long non-performance periods, EVA application should be considered as a means of functionally verifying the payload descent vent mechanisms (pressure equilization) operation prior to earth return. The on-orbit maintenance tasks applicable to the OTA/SI elements could be increased signficantly by providing a minimum contamination mode of operation for the EMU. Assuming an RMS failure, use of EVA with the MMU should be reviewed as a potential backup mode for deployment and/or retrieval and berthing the LST payload with the Shuttle Orbiter.

2.4.3.4 LST EVA Task Definition

Analysis of the LST preliminary payload design and program definition has resulted in the identification of characteristic tasks within the capabilities of EV crewmen and the EVA support systems. The tasks listed in Table 2.4.3 are not intended to be a design review of the payload or associated support systems but rather to illustrate the significant range of EVA capabilities available to the payload community and acquaint EVA system designers with payload requirements. The tasks listed in Table 2.4.3 are typical of the twelve classifications defined in Table 2.1.1

and require specific sub-task performance for completion. EVA task outlines are developed in subsequent subsections to define the requirements, identify sub-tasks and provide supplementary information associated with the major task functions. Typical EVA tasks were selected to develop representative EVA mission scenarios; preliminary EVA procedures and timelines were developed from the scenarios.

2.4.4 LST EVA Mission Scenarios, Timelines and Procedures

The LST preliminary design and program definition studies have identified candidate subsystem equipment for both planned and unscheduled on-orbit LST service and maintenance. To demonstrate the versatility of EVA systems application, two hypothetical EVA missions were defined from the LST representative tasks identified in Table 2.4.3. Several separate tasks were selected and combined to develop typical payload EVA servicing missions. The LST mission scenario no. 1 represents payload operations for scheduled maintenance and involves various vehicle/payload subsystems and locations. The second LST mission scenario assumes a malfunction of an appendage mechanism in the deployed position which impedes safe RMS engagement for free space capture and berthing to the Orbiter.

2.4.4.1 LST EVA Mission Scenario No. 1 -- LST Scheduled Maintenance

The basis of LST EVA mission scenario no. 1 is planned on-orbit maintenance necessary to retain spacecraft operating proficiency. Several tasks were selected from the "planned EVA" category identified in Table 2.4.3. A hypothetical mission was developed by combining the tasks into a typical payload service mission using the "unaided EVA" operational mode.

The principal EVA function in the mission is to remove/replace (ref. Table 2.1.1) support systems modular equipment and scientific instruments:

- 3 battery chassis in the SSM equipment section
- 2 reference gyro assemblies on the focal plane structure

- 1 star tracker assembly on the focal plane structure
- 1 SI module in the SSM aft compartment.

The selection criteria for replacement of the LST units assumed that one or more of the following have occurred: (a) operational life limit standards approached or exceeded, (b) unacceptable degradation in performance, or (c) upgrading scientific capability required. Two EVA crew members are employed to effect maximum efficiency in the overall operations. The major tasks, principle sub-tasks involved, and task performance rationale are contained in Table 2.4.4.

2.4.4.2 LST EVA Task Completion Plans -- Mission Scenario No. 1

The LST task completion plans for mission scenario no. 1 provide a preliminary set of procedures and timelines to demonstrate that the selected EVA payload tasks can be accomplished by application of the Shuttle EVA system. The task completion plans identify principle elements of the EVA mission and the extravehicular mission support requirements including number of crewmen, EVA mission time, translation aids and location, restraints, tools and lighting.

The EVA timelines and procedures for the planned LST scheduled maintenance (mission scenario no. 1), including identification of payload interfaces and special requirements, are provided in Table 2.4.5. Assumptions associated with the mission scenario include the following:

- Two qualified Orbiter crewmembers are available for conducting EVA's. A third crewmember is available as required to perform Payload Station extravehicular supporting functions.
- Sufficient crew mobility aids (i.e., handholds, handrails) are provided by the payload and/or Shuttle Orbiter to access the LST and spares/support stowage areas from the airlock.
- Given the requirements for planned EVA, crew mobility aids and restraints (i.e., tether attach points, handholds, foot restraints) are provided by the payload for access/restraint at each LST worksite.

TABLE 2.4.4: LST EVA Tasks--Mission Scenario No. 1

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
LST SCHEDULED MAINTENANCE ⇩	Perform a two-man "Planned" EVA to remove and replace support systems equipment and LST science instruments as part of scheduled on-orbit maintenance. Replacement consists of: -3 battery chassis in SSM Equipment Section -2 reference gyro and one star tracker on the OTA Focal Plane Assembly (FPA) -1 SI module in SSM aft compartment	Assumes replacement required because equipment and SI's are operationally life limited or performance degradation has occurred
1. LST STABILIZING STRUT INSTALLATION	RMS capture, stabilization, retrieval and docking of LST to Orbiter in on-orbit maintenance position completed. LST systems are in passive maintenance configuration. Payload bay lights activated.	Note: SSE equipment storage racks assumed to be located above OMS kit at aft end of payload bay.
• Egress airlock and translate to equipment stowage racks	Crewmen translation using handrails along payload bay to equipment stowage racks	Requires crew mobility aids to stowage area
• Ingress foot restraints/ unstow stabilizing strut	Retrieve stabilizing strut after tethering to crewman	Two pair fixed foot restraints required at stowage area; strut provided as payload SSE
• Install stabilizing strut	Install stabilizing strut between LST and equipment stowage rack	Required to stabilize LST during maintenance and allow RMS disengagement

TABLE 2.4.4: LST EVA Tasks--Mission Scenario No. 1 (Continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
• Monitor RMS disengagement from payload	Crewmen translate clear of LST; observe RMS disengagement and stowage	Operation from Orbiter cabin payload station; tethered crewmen observe operations from safe location
2. PORTABLE LIGHT PLACEMENT		
• Unstow/install portable lights	Retrieve and attach portable light assemblies to equipment rack handrail; connect and activate lights to illuminate anti-sun side of LST	Lights provided as payload SSE to illuminate payload exterior worksites; Utility electrical outlets required in payload bay
3. WORKSITE PREPARATION FOR BATTERY CHASSIS REPLACEMENT		
• Unstow tools/equipment	Retrieve EVA support equipment items from stowage rack	Two-man operations; requires portable workstation, handtools, tethers, and equipment transfer rod provided as payload SSE Note: From this point EV crewmen perform separate tasks simultaneously; CM1 at LST worksites, CM2 at stowage site.

TABLE 2.4.4: LST EVA Tasks--Mission Scenario No. 1 (Continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
• Transfer support equipment to SSM equipment section	CM1 hand carries workstation, tethers to worksite (Bay 5A) using handrails on LST	Handtools in kit as part of workstation; mobility aids provided by payload
• Deploy workstation and support equipment at worksite	CM1 attach/deploy/ingress portable workstation; activate workstation light to illuminate work area and deploy tethers and tool kit	Requires portable workstation interface or "universal" attachment fixture; battery powered adjustable light provided in workstation design
	Install equipment transfer rod between worksite (Bay 5A) and stowage rack	Two-man operation
	CM2 attach/deploy tool kit/tethers at SSE stowage rack	Attachment interfaces required on rack
4. BATTERY CHASSIS 5A REPLACEMENT	CM1 Operations	
• Remove used chassis from bay	Perform required removal operations and temporarily tether aside used chassis 5A	Eight captive bolts around chassis perimeter; chassis hinge mounted with ball joint and slot design for ease of removal; four std. electrical connectors on hinge side bay bracket

TABLE 2.4.4: LST EVA Tasks--Mission Scenario No. 1 (Continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
• Obtain/mount replacement chassis	Using tether, remove replacement chassis from equipment transfer rod and engage hinges to open position	Replacement chassis arrived at worksite thru CM2 operations
• Dispose of used chassis	Attach used chassis to equipment transfer rod and detach tether	Allows CM2 to continue separate simultaneous operations
• Install replacement chassis	Install replacement chassis to operational configuration	Reverse of removal operations
	CM2 Operations	
• Unstow replacement chassis	Using tether, perform operations to remove replacement chassis 5A from stowage rack	Eight captive bolts on chassis perimeter; rack mounted dummy connectors provide electrical interface protection
• Transfer replacement chassis to CM1 worksite	Attach replacement chassis to equipment transfer rod and remove tether; transfer to CM1 worksite	Spring loaded self-adjusting clip mechanism holds chassis to carriage plate and hand-crank provides mobility interface on equipment transfer rod
• Transfer/stow used chassis	Await CM1 chassis exchange; transfer used chassis 5A to stowage site and remove from equipment transfer rod using tether; install where replacement unit removed from	Reverse of removal operations, pull tab at each equipment stowage location uncovers marker to indicate used units

TABLE 2.4.4: LST EVA Tasks--Mission Scenario No. 1 (Continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
	stowage rack; pull used equipment tab at rack location	
5. BATTERY CHASSIS 5B REPLACEMENT		
• Retrieve workstation and equipment/transfer to next worksite (repeat applicable steps in item 3 above)	CM1 transfers workstation and all support equipment to new worksite (Bay 5B) and performs operations same as for previous battery chassis replacement (5A) preparation	CM2 assists as required from SSE stowage rack worksite
• Repeat steps in item 4 above	Perform operations identical to battery chassis 5A replacement to replace 5B	Two-man operations
6. BATTERY CHASSIS 4B REPLACEMENT		
• Repeat steps in item 5 above	Perform operations identical to battery chassis 5A replacement to replace 4B	Two-man operations
• Stow unneeded support equipment	Remove equipment transfer rod from last worksite and restow in equipment stowage rack	Removal is two-man operation; reverse of installation and unstowing operations

TABLE 2.4.4: LST EVA Tasks--Mission Scenario No. 1 (Continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
• Stow tools/light on workstation	Temporarily stow tools in kit, deactivate/stow light on workstation and egress workstation	CM1 Operations
7. WORKSITE PREPARATION FOR GYRO AND STAR TRACKER REPLACEMENT	CM1 Operations	
• Retrieve workstation, equipment and transfer to next worksite	Disengage portable workstation and transfer to port side of FPA access door (-V3 axis)	Equipment tethered to translating crewman
• Open access door/attach/deploy/ingress workstation, activate lights	Open FPA access door; setup and ingress portable workstation in door opening; activate workstation light to illuminate work area and redeploy tool kit; activate interior FPA fixed lights	Three latch levers and rachet operated open/close door mechanisms designed for one-hand operations; requires portable workstation interface or "universal" attachment fixture; fixed lights required to illuminate FPA mounted equipment and powered via Orbiter/LST umbilical

TABLE 2.4.4: LST EVA Tasks--Mission Scenario No. 1 (Continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
8. REF. GYRO ASSEMBLY NO. 1 REPLACEMENT	CM1 Operations	
• Remove used gyro from FPA	Perform required removal operations and tether ref. gyro assembly no. 1	Two std. electrical connectors on package upper surface; six captive bolts (three each end) on package; removal from compartment is two-hand operation to safely clear other FPA mounted equipment/structure
• Obtain replacement gyro	Using second tether, hand exchange used ref. gyro assembly for replacement unit with CM2	CM2 has performed separate simultaneous tasks to obtain replacement unit from stowage
• Install replacement gyro	Install replacement ref. gyro assembly to operational configuration	Reverse of removal operations Orientation marks and guide pins on gyro package and FPA mounting surface, respectively
	CM2 Operations	
• Unstow replacement gyro	Using tether perform operations to remove replacement ref. gyro assembly no. 1 from stowage rack	Six captive bolts on package (3 each end); rack tethered caps provide electrical interface protection

TABLE 2.4.4: LST EVA Tasks--Mission Scenario No. 1 (Continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
• Exchange replacement gyro for used package	Perform hand exchange with CM1 as noted above	Two-man operation
• Stow used gyro	Install used ref. gyro assembly no. 1 where replacement unit removed from stowage rack; pull used equipment tab at rack location	Reverse of removal operations
9. <u>REF. GYRO ASSEMBLY NO. 2 REPLACEMENT</u>		
• Repeat steps in item 8 above	CM1 adjust workstation; perform operations identical to ref. gyro assembly no. 1 replacement to replace no. 2	Two-man operations
10. <u>CENTER STAR TRACKER REPLACEMENT</u>	<u>CM1 Operations</u>	
• Remove used star tracker from FPA	Perform required removal operations and tether center fixed star tracker	One std. electrical connector on package; two self-locking thumb screw (one/side) fasteners hold shade to tracker; four captive bolts (two/side) on package; removal from compartment is two-hand operation for safety

TABLE 2.4.4: LST EVA Tasks--Mission Scenario No. 1 (Continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
• Obtain replacement star tracker	Using second tether, hand exchange used star tracker package for replacement unit with CM2	CM2 has performed separate simultaneous tasks to obtain replacement unit from stowage
• Install replacement star tracker	Install replacement center fixed star tracker to operational configuration	Reverse of removal operations, Alignment guides/stops on tracker, shade and FPA mounting surface
	CM2 Operations	
• Repeat CM2 steps in item 8 above substituting star tracker for gyro	Perform operations similar to ref. gyro assembly replacement	Four captive bolts; rack tethered caps provide electrical and optical interface protection
11. WORKSITE CLOSEOUT FOR GYRO AND STAR TRACKER REPLACEMENT		
• Deactivate lights/retrieve workstation and equipment/close access door	CM1 prepare worksite for FPA access door closure; transfer portable workstation and support equipment to CM2; perform door seal inspection, deactivate interior FPA fixed lights and close access door	Reverse of preparation procedures; Door seal inspection assures acceptable stray light/contamination barrier

TABLE 2.4.4: LST EVA Tasks--Mission Scenario No. 1 (Continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
• Stow workstation and EVA support equipment	CM2 accept portable workstation and support equipment from CM1 and replace in stowage rack	Tether required; CM2 proceeds to SI module exchange preparation tasks
12. <u>WORKSITE PREPARATION FOR SI MODULE REPLACEMENT</u>	<u>CM1 Operations</u>	
• Transfer to new worksite/open access door/activate lights	Translate to and open -V2 axis aft compartment door; activate interior compartment fixed lights	Four latch levers and rachet operated open/close door mechanisms designed for one-hand operation; mobility aids provided by payload; fixed lights required to illuminate SI module interfaces and powered via Orbiter/LST umbilical
• Install SI module monorail transfer system	Ingress foot restraints and assist CM2 in completing SI module monorail transfer system installation between stowage rack and SI module no. 2	Two pr. fixed foot restraints provided by payload at each SI worksite (aft bulkhead) Monorail system provided as payload SSE and designed with one-hand operated captive fasteners to interface LST aft bulkhead mounting

TABLE 2.4.4: LST EVA Tasks--Mission Scenario No. 1 (Continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
	CM2 Operations	
• Unstow/install SI module monorail transfer system	Using tethers, remove SI module monorail transfer system from stowage rack; beginning installation at SI module stowage rack, assemble/install monorail system forward to SI module no. 2 in LST aft compartment; CM1 to assist when available	Monorail transfer system consist of self-aligning interconnecting track sections and two transfer carriages; Crew mobility aids and tether points required along installation path
13. SI MODULE NO. 2 REPLACEMENT	CM1 Operations	
• Attach monorail carriage to SI module	Transfer, align and install monorail carriage--one to SI module no. 2	Carriage design provides one-hand operated controls/mechanisms for base interface lateral and vertical alignment adjustment, elevation and rotational positioning and hand brake; Three hand operated captive fasteners in mounting plate for module attachment

TABLE 2.4.4: LST EVA Tasks--Mission Scenario No. 1 (Continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
• Remove used SI module from FPA mounting	Perform required removal operations and tether SI module no. 2; transfer used module to CM2 waiting at stowage rack; detach tether after handover	Three std. electrical connectors; one quick disconnect at grd. N_2 purge interface; two base attachment latches at module fwd. end; lowering monorail carriage plate disengages module axial alignment/retaining pin from FPA pyramidal support structure; module provided with handholds; monorail track used as mobility/restraint aid along translation path
• Obtain replacement SI module	Tether and transfer replacement SI module no. 2 to LST aft compartment	Replacement module at standby track section thru separate simultaneous operations of CM2
• Install replacement SI module	Position replacement SI module no. 2 within FPA pyramidal support structure and return to operational configuration	Reverse of removal operations; alignment guides/stops provided on FPA support structure
• Detach/remove monorail carriage from SI module	Disengage and remove monorail carriage-one from SI module no. 2	Reverse of attachment operations

TABLE 2.4.4: LST EVA Tasks--Mission Scenario No. 1 (Continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
	CM2 Operations	
o Unstow replacement SI module	Transfer, align and install monorail carriage 2 to replacement SI module no. 2 and perform operations to remove from stowage rack; tether and rotate module to vertical position and transfer onto monorail standby track section; detach tether and await CM1 delivery of used module	Module stowed in horizontal position; rack tethered caps provide N_2 purge Q.D. and electrical interface protection; module base latches and axial alignment/retaining pin used to mount module in stowage rack; stowage rack handrail and monorail track used as crewman mobility/restraint aids
• Stow used SI module	Using tether, accept used SI module no. 2 from CM1 and complete transfer to stowage rack; install where replacement module removed; pull used equipment tab at rack location	Reverse of removal operations, CM2 proceeds to removal of SI module monorail transfer system at completion
14. WORKSITE CLOSEOUT FOR SI MODULE REPLACEMENT		
• Remove SI module monorail transfer system/stow	CM1 assist CM2 in removing SI module monorail transfer system; Using tethers, disassemble and transfer to stowage rack; CM2 perform stowage of system	Two-man operations; reverse of installation and unstowing operations

TABLE 2.4.4: LST EVA Tasks--Mission Scenario No. 1 (Continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
• Deactivate lights, retrieve tethers, close access door	CM1 prepare aft compartment worksite for access door closure; remove tethers, perform door seal inspection, deactivate interior fixed lights and close access door	Reverse of preparation operations; Door seal inspection assures acceptable stray light/contamination barrier
15. PORTABLE LIGHT REMOVAL		
• Stow tools and EVA support equipment	Crewmen stow all EVA support items and tools in stowage rack	Reverse of removal operations
• Remove/stow portable lights	Deactivate, retrieve and stow portable light assemblies at equipment stowage rack	Reverse of installation and unstowing operations
16. LST STABILIZING STRUT REMOVAL		Note: LST stabilizing strut removal performed if subsequent EVA operations are not planned.
	Verify EV crewmen clear of LST; observe RMS engagement and stabilization of LST	Operation from Orbiter cabin payload station; tethered crewmen observe operation from safe location
• Remove/stow stabilizing strut	Using tether, remove and stow payload stabilizing strut in equipment stowage rack	Reverse of installation and unstowing operations

TABLE 2.4.4: LST EVA Tasks--Mission Scenario No. 1 (Continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
• Secure equipment stowage rack	Closeout equipment stowage racks for Orbiter entry	
• Translate to and ingress airlock		<u>TASKS COMPLETE</u>

TABLE 2.4.5: LST EVA Task Completion Plans -- Mission Scenario No. 1

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: LST Scheduled Maintenance — MODE: UNAIDED EVA — Sheet 1 of 17

TIME (Min.) CUM.	TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	EVA CM2	OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
		1.0	Prepare for planned two-man EVA to remove and replace SSM equipment and LST scientific instruments; 3 battery chassis in SSM equipment Section, 2 reference gyro and one star tracker on the OTA Focal Plane Assembly (FPA) and one SI module in SSM aft compartment.			LST systems in passive maintenance configuration.	LST capture and docking for on-orbit maintenance completed prior to crewman egress.
4.5	4.5	1.1	Egress airlock and translate to equipment stowage racks	Egress airlock and translate to equipment stowage racks	Payload Station: payload bay lighting activated	Orbiter airlock and payload bay handrails (bulkhead and doors)	
7.0	2.5	1.2	Ingress foot restraints; retrieve and tether LST stabilizing strut	Ingress foot restraints; Assist CM1		EMU tether	Foot restraints (2 sets) provided at stowage racks; strut provided as payload SSE
13.0	6.0	1.3	Install stabilizing strut (adjust length as required) between LST and stowage rack and remove tether	Assist CM1		LST (-V3 axis) aft station and SSE equipment stowage rack	Strut provides LST stabilization during maintenance when RMS disengaged
17.0	4.0	1.4	Egress foot restraints, translate and tether to starboard side of equipment rack handrail; Notify Orbiter payload station crew clear for RMS disengagement; monitor operations	Egress foot restraints, translate and tether to starboard side of equipment rack handrail; monitor RMS disengagement operations	Payload Station: disengage and stow RMS when crew clear of LST	SSE equipment stowage rack handrails; RF voice communications	*Handrail provided laterally accross equipment stowage rack
17.0	17.0						

* EVA support equipment required to complete LST Mission Scenario No. 1 to be provided by payload

TABLE 2.4.5: LST EVA Task Completion Plans -- Mission Scenario No. 1 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: LST Scheduled Maintenance

Sheet 2 of 17

TIME (Min.)		SEQ.	FUNCTION AND CREW TASK			SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
CUM.	TASK		EVA CM1	EVA CM2	OTHER SUPPORT		
		2.0	Portable light placement to illuminate LST exterior worksites				
1.5	1.5	2.1	Ingress foot restraints at equipment stowage rack; unstow portable light assemblies and tether	Ingress foot restraints at equipment stowage rack; assist CM1			*Portable light assemblies (2) provided as payload SSE
6.0	4.5	2.2	Install, connect cable and adjust portable light on port end of equipment rack handrail to illuminate LST anti-sun side worksites	Install, connect cable and adjust portable light on starboard end of equipment rack handrail	Orbiter electrical power system	SSE equipment stowage rack handrails; payload bay utility electrical outlets	Utility electrical outlets required in Orbiter payload bay at equipment stowage racks
23.0	6.0						
		3.0	SSM equipment section worksite preparation for battery chassis replacement				
2.5	2.5	3.1	Unstow portable workstation and 3 equipment tethers; tether equipment to EMU	Unstow and deploy tool kit and 3 equipment tethers at SSE stowage rack		SSE equipment stowage rack; EMU tether	*Support equipment required • 1 portable workstation with tool kit/hand tools and adjustable battery powered light • 6 equipment tethers • 1 tool kit/hand tools

*EVA support equipment required to complete LST Mission Scenario No. 1 to be provided by payload

TABLE 2.4.5: LST EVA Task Completion Plans -- Mission Scenario No. 1 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: LST Scheduled Maintenance

Sheet 3 of 17

TIME (Min.) CUM.	TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	EVA CM2	OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
5.0	2.5	3.2	Translate to worksite (SSM equipment bay 5A) with support equipment and stabilize	Unstow, tether and deploy equipment transfer rod; locate carriage plate at stowage rack end of rod		LST exterior longitudinal and circumferential handrails; SSE equipment stowage rack	*Equipment transfer rod provided as payload SSE
9.5	4.5	3.3	Deploy, attach and ingress portable workstation; activate and adjust workstation light; deploy tool kit and equipment tethers	Continue same as above		LST/SSM equipment section exterior	Hand tool tethers provided as part of tool kit; workstation light used to illuminate immediate work areas
14.5	5.0	3.4	Accept end of equipment transfer rod from CM2 and attach at worksite	Attach equipment transfer rod base socket to stowage rack and extend end to CM1		LST circumferential handrail; SSE equipment stowage rack	
37.5	14.5						
			4.0 SSM battery chassis 5A removal/replacement				
2.5	2.5	4.1	Unstow, assemble and tether hand tools to workstation	Unstow, assemble and tether hand tools to stowage rack		EVA portable workstation SSE equipment stowage rack	*Tools required: 3/8" drive rachet wrench, 4" extension, socket and torque wrench at each worksite
9.0	6.5	4.2	Loosen eight captive bolts around battery chassis 5A perimeter	Loosen eight captive bolts holding replacement battery chassis 5A in stowage rack		Battery chassis mounts at equipment bay and stowage rack	Floating nutplates attached to back surface of mounting structure

*EVA support equipment required to complete LST Mission Scenario No.1 to be provided by payload

TABLE 2.4.5: LST EVA Task Completion Plans -- Mission Scenario No. 1 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: LST Scheduled Maintenance

Sheet 4 of 17

TIME (Min.) CUM.	TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	EVA CM2	OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
11.0	2.0	1.3	Swing chassis to open position; disconnect four electrical connectors from bay bracket	Swing chassis up and disconnect four electrical connectors from stowage rack bracket		Equipment bay 5A electrical connector bracket; stowage rack dummy connector bracket	Hinge mounted chassis; Std. twist type electrical connectors
13.0	2.0	1.4	Attach tether and remove used chassis from bay hinges; temporarily tether aside	Attach tether and remove replacement chassis from stowage rack hinges		Chassis hinges	Ball joint and slot designed chassis hinges for ease of removal
19.0	6.0	1.5	Rest	Mount replacement chassis to equipment transfer rod carriage; remove tether and transfer chassis to CM1 worksite using hand crank on transfer rod		Equipment transfer rod	Spring loaded, self-adjusting clip mechanism holds chassis to carriage plate during translation
23.0	4.0	1.6	Attach tether and remove replacement chassis from equipment transfer rod carriage; engage chassis hinges, swing to open position and remove tether	Rest		Equipment transfer rod; chassis hinges	
28.5	5.5	1.7	Mount used chassis to equipment transfer rod carriage and remove tether	When CM1 has used chassis mounted, transfer to stowage rack using hand crank on transfer rod		Equipment transfer rod	

TABLE 2.4.5: LST EVA Task Completion Plans -- Mission Scenario No. 1 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: LST Scheduled Maintenance

Sheet 5 of 17

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
32.5	4.0	4.8	On replacement battery chassis 5A connect four electrical connectors at bay bracket	Attach tether and remove used chassis from equipment transfer rod carriage; engage chassis hinges, swing to up position and remove tether		Equipment bay 5A electrical connector bracket; equipment transfer rod; chassis hinges at stowage rack	Used chassis stowed where replacement unit was removed from equipment stowage rack
40.5	8.0	4.9	Visually inspect bay/chassis and swing chassis closed; engage and torque eight captive bolts around chassis 5A perimeter	Connect four electrical connectors from used chassis to stowage rack bracket; swing chassis to stowed position, engage and torque eight captive bolts around perimeter; pull used equipment tab at rack location		Battery chassis mounts at equipment bay and stowage rack	Pull tab at stowage rack location exposes visual marker to indicate used equipment occupancy.
78.0	40.5						
		5.0	SSM battery chassis 5B removal/replacement				
4.5	4.5	5.1	Egress workstation; detach workstation and tool kit and transfer to new worksite (SSM equipment bay 5B); attach and ingress portable workstation; adjust workstation light; transfer equipment transfer rod to new worksite	Monitor CM1 operations and assist in equipment transfer rod adjustments and relocation to new SSM equipment section worksite		LST handrails; equipment transfer rod	Equipment transfer rod base ball socket remains attached to stowage rack

TABLE 2.4.5: LST EVA Task Completion Plans -- Mission Scenario No. 1 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: LST Scheduled Maintenance

Sheet 6 of 17

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
41.0	36.5	5.2	Repeat sequences 4.2 through 4.9 for battery chassis 5B				
119.0	41.0						
			6.0 SSM battery chassis 4B removal/replacement				
41.5	41.0	6.1	Repeat sequences 5.1 and 4.2 through 4.9 for battery chassis 4B				
45.5	4.5	6.2	Detach equipment transfer rod at last worksite for CM2; temporarily stow tools in kit and deactivate/stow light on workstation; egress workstation	Accept equipment transfer rod from CM1; using tether, detach rod base socket at stowage rack and restow in rack		LST handrails; SSE equipment stowage rack	Equipment transfer rod not required for subsequent operations
64.5	45.5						
			7.0 Focal Plane Assembly (FPA) worksite preparation for reference gyro assemblies and star tracker replacement				
1.5	1.5	7.1	Retrieve portable workstation with support equipment and translate to next worksite at FPA access door	Assist CM1 upon arrival at FPA worksite access door		EMU tether; LST handrails	FPA access door located on -V3 LST axis (facing aft payload bay bulkhead)

TABLE 2.4.5: LST EVA Task Completion Plans -- Mission Scenario No. 1 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: LST Scheduled Maintenance

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TIME (Min.) CUM.	TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	EVA CM2	OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
6.0	4.5	7.2	Open FPA access door; deploy, attach and ingress portable workstation; activate and adjust workstation light; deploy tool kit/equipment tethers; activate interior FPA fixed lights	Assist CM1 in opening FPA access door		FPA access door latch and opening mechanisms; LST handrails; FPA interior fixed light switch	Three one-hand operated double-acting latch levers release hinged access door; rachet operated open/close mechanism at door hinge line incorporates auto position lock; *Fixed lights powered by Orbiter via umbilical
170.5	6.0						
		8.0	SSM reference gyro assembly no.1 removal/replacement				
2.0	2.0	8.1	Unstow, assemble and tether handtools to workstation	Ingress foot restraints at equipment stowage rack; exchange, assemble and tether handtools to stowage rack		EVA portable workstation SSE equipment stowage rack	*Tools required: 3/8" drive rachet wrench, 8" extension, socket and torque wrench at each worksite
3.5	1.5	8.2	Locate ref. gyro no.1 on FPA support structure (toward +V2 axis) and disconnect two electrical connectors on upper case surface	Locate replacement ref. gyro; remove and temporarily stow caps from two electrical connectors on upper case surface		Ref. gyro assemblies at FPA and stowage rack	Std. twist type electrical connectors; stowage rack tether caps provided as SSE to protect electrical interfaces on ref. gyro

*EVA support equipment required to complete LST Mission Scenario No.1 to be provided by payload

TABLE 2.4.5: LST EVA Task Completion Plans -- Mission Scenario No. 1 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: LST Scheduled Maintenance

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TIME (Min.) CUM.	TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	EVA CM2	OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
8.5	5.0	8.3	Attach equipment tether to used ref. gyro assembly no.1; loosen six captive bolts (three each end) from unit	Attach equipment tether to replacement ref. gyro assembly and loosen six captive mounting bolts		Ref. gyro mounting structure on FPA and stowage rack	Lock nuts are captive on mounting structure
10.0	1.5	8.4	Using two-hands, maneuver used ref. gyro no.1 outboard and aft to exit access door	Remove replacement ref. gyro from stowage rack and prepare to exchange units with CM1			Removal/installation of equipment mounted on FPA is two-hand operation to ensure safe clearance and protection of hardware
11.0	1.0	8.5	Using second tether, hand exchange used for replacement ref. gyro assembly no. 1 with CM2	Perfrom ref. gyro assembly exchange with CM1 using equipment tethers		Equipment tethers	Direct hand exchange of equipment between crewmen by effective use of tethers
17.5	6.5	8.6	Using two hands, maneuver replacement ref. gyro no. 1 through access door and inboard to FPA; align orientation mark on gyro and slip over mounting surface guide pins; engage and torque six captive bolts; remove equipment tether	Transfer used ref. gyro assembly to equipment stowage rack; guide onto rack mounting surface, engage and troque six captive bolts; remove equipment tether		Ref. gyro mounting structure on FPA and stowage rack	Used ref. gyro stowed where replacement unit was removed from equipment stowage rack

TABLE 2.4.5: LST EVA Task Completion Plans -- Mission Scenario No. 1 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: LST Scheduled Maintenance

Sheet 9 of 17

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
19.0	1.5	8.7	Connect two electrical connectors on upper case surface of replacement ref. gyro No.1 assembly	Install protective caps on two electrical connectors on ref gyro upper case surface; pull used equipment tab at rack location		Ref. gyro assemblies at FPA and storage rack	
189.5	19.0						
			9.0 SSM reference gyro assembly No.2 removal/replacement				
17.0	17.0	9.1	Adjust workstations and repeat sequences 8.2 through 8.7 for reference gyro assembly No.2				
205.5	17.0						
			10.0 SSM center star tracker removal/replacement				
1.0	1.0	10.1	Adjust portable workstation for center star tracker removal	Assist CM1		EVA portable workstation	*Tools required: same as for ref. gyro type replacement
2.5	1.5	10.2	On center star tracker, disconnect one electrical connector	Locate replacement center star tracker; remove and temporarily stow cap from one electrical connector		Star trackers at FPA and storage rack	Std. twist type electrical connector

*EVA support equipment required to complete LST Mission Scenario No.1 to be provided by payload

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TABLE 2.4.5: LST EVA Task Completion Plans -- Mission Scenario No. 1 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: LST Scheduled Maintenance

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TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
4.5	2.0	10.3	Loosen two captive thumb screws (one each side) on star tracker shade; slide shade outboard to clear optics interface	Remove and temporarily stow protective cap from star tracker optics		Star tracker optics at FPA and stowage rack	Self-locking captive thumb screws on shade; nuts are captive on tracker interface
9.0	4.5	10.4	Attach equipment tether to center star tracker; loosen four captive bolts (two each side) from unit	Attach equipment tether to replacement star tracker and loosen four captive mounting bolts		Center star tracker mounting sturcture on FPA and stowage rack	Lock nuts are captive on mounting structure
10.5	1.5	10.5	Using two-hands, maneuver used center star tracker outboard and aft to exit access door	Remove replacement star tracker from stowage rack and prepare to exchange units with CM1			
11.5	1.0	10.6	Using second tether, hand exchange used star tracker for replacement with CM2	Perform star tracker exchange with CM1 using equipment tethers		Equipment tethers	Direct hand exchange of equipment
18.0	6.5	10.7	Using two hands, maneuver replacement star tracker through access door, fwd. and inboard to center FPA mount; slide into alignment guides until against stops; engage and torque four captive bolts; remove equipment tether	Transfer used star tracker to equipment stowage rack; guide onto rack mounting surface; engage and torque four captive bolts; remove equipment tether		Star tracker mounting structure on FPA and stowage rack	Used star tracker stowed where replacement unit was removed from equipment stowage rack

TABLE 2.4.5: LST EVA Task Completion Plans -- Mission Scenario No. 1 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: LST Scheduled Maintenance

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TIME (Min.)		SEQ.	FUNCTION AND CREW TASK			SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
CUM.	TASK		EVA CM1	EVA CM2	OTHER SUPPORT		
22.0	4.0	10.8	Align and slide center star tracker shade inboard to interface tracker optics; engage and tighten two captive thumb screws	Replace protective cap on one electrical connector of used star tracker; pull used equipment tab to rack location		Star tracker at FPA and stowage rack	
228.5	22.0						
		11.0 Focal plane assembly worksite closeout after equipment replacement					
4.0	4.0	11.1	Stow all hand tools in tool kit, deactivate light, and stow kit and light on workstation; retrieve equipment tethers and attach to EMU; egress portable workstation and detach from worksite; transfer workstation to CM2	Accept portable workstation from CM1 (hand exchange); stow workstation in equipment stowage rack		Portable workstation; SSE equipment stowage rack; EMU tether	Portable workstation not required for subsequent operations
7.5	3.5	11.2	Inspect FPA access door seal; deactivate interior FPA lights; close and latch door	Assist CM1 in closing FPA access door		LST handrails, FPA interior fixed light switch; FPA access door seal, closing and latch mechanisms	Inspection assures acceptable stray light/contamination barrier
236.0	7.5						

TABLE 2.4.5: LST EVA Task Completion Plans -- Mission Scenario No. 1 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: LST Scheduled Maintenance

Sheet 12 of 17

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
		12.0	LST aft compartment worksite preparation for SI module replacement				
6.0	6.0	12.1	Translate to -V2 axis LST aft compartment access door; stabilize and open door; activate interior fixed lights	Using tethers, retrieve SI module monorail transfer system from stowage rack; assemble/install system beginning at SI module stowage rack and work forward toward SI module no.2 in LST aft compartment		LST handrails; LST -V2 axis aft compartment access door latch and opening mechanisms; interior fixed light switch; SSE equipment stowage rack; Orbiter payload bay door handrails	Aft compartment access doors design and operation same as FPA door except four double-acting latch levers; * monorail transfer system consist of self-aligning interconnecting track sections with two transfer carriages; *fixed interior lights powered by Orbiter via umbilical
24.0	18.0	12.2	Translate into aft compartment and ingress foot restraints; assist CM2 to complete SI module monorail transfer system installation to SI module no.2	Continue SI module monorail transfer system assembly and installation		LST aft compartment; SI module stowage rack	*Foot restraints (2 sets/module) provided at each SI worksite on aft bulkhead for attachment
260.0	24.0						

*EVA support equipment required to complete LST Mission Scenario No.1 to be provided by payload

TABLE 2.4.5: LST EVA Task Completion Plans -- Mission Scenario No. 1 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: LST Scheduled Maintenance

Sheet 13 of 17

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
		13.0	SI module no.2 removal/replacement				
6.0	6.0	13.1	Transfer, align and attach monorail carriage-one to SI module no.2; engage and tighten three hand operated captive fasteners in carriage plate; engage carriage brake	Transfer monorail carriage-two to replacement SI module no.2 in stowage rack; rotate carriage to horizontal position, align and attach to module; engage and tighten three hand-operated captive fasteners; engage carriage brake		Monorail transfer system carriages and SI modules in aft compartment and at stowage rack	Monorail carriage design provides one-hand operated controls/mechanisms for alignment adjustment, base position and manual brake; lock nuts are captive on module for carriage attachment
10.5	4.5	13.2	On SI module no. 2, disconnect three electrical connectors and one GN_2 quick disconnect (Q.D.)	On replacement SI module no.2, remove and temporarily stow caps from three electrical connectors and one GN_2 Q.D.		SI modules	Std. twist type electrical connectors; Std. double-acting Q.D. connector
12.5	2.0	13.3	Attach tether to module handhold and release two base attachment latches from FPA structure	Attach tether to replacement module and release two base attachment latches from storage rack		SI module mounting structure on FPA and stowage rack	Double acting base latches hold module in position along with module axial alignment/retaining pin (similar mounting in stowage rack except module in horizontal position)

TABLE 2.4.5: LST EVA Task Completion Plans -- Mission Scenario No. 1 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: LST Scheduled Maintenance

Sheet 14 of 17

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
24.5	12.0	13.4	Lower monorail carriage and release hand brake; egress foot restraints and transfer used SI module no. 2 to CM2 at stowage rack using tether	Release monorail carriage hand brake, move to disengage retaining pin and re-engage brake; rotate module/carriage to vertical position, release hand brake and transfer replacement SI module no.2 onto monorail standby-track section; engage brake and detach tether		Monorail system carriages and track, tethers, and stowage rack handrail	Lowering carriage base plate disengages module axial alignment/retaining pin from mounting structure
38.5	14.0	13.5	Hand used SI module no.2 to CM2 and switch tether to replacement module; release carriage hand brake and transfer replacement module to LST aft compartment; align module within FPA pyramidal support structure and raise carriage to engage module alignment/ retaining pin; engage carriage brake	Accept used SI module no.2 from CM1, attach tether and transfer to stowage rack; engage carriage brake; rotate module to horizontal position, release brake and move to engage module retaining pin; re-engage hand brake when module against stop		Same as above	
41.0	2.5	13.6	Engage two base attachment latches to FPA structure on replacement SI module no.2 and detach tether	Engage two base attachment latches to stowage rack on used SI module no.2 and detach tether		SI module mounting structure on FPA and stowage rack	Used SI module stowed where replacement unit was removed from spare equipment stowage rack

TABLE 2.4.5: LST EVA Task Completion Plans -- Mission Scenario No. 1 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: LST Scheduled Maintenance

Sheet 15 of 17

TIME (Min.) CUM.	TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	EVA CM2	OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
45.0	4.0	13.7	On replacement SI module no.2, connect three electrical connectors and one GH_2 Q.D.	On used SI module no.2, replace protective caps on three electrical connectors and one GH_2 Q.D.		SI module	
48.5	3.5	13.8	Loosen three hand operated captive fasteners in carriage plate; release hand brake, lower carriage and remove from replacement SI module	Loosen three hand operated captive fasteners in carriage plate; rotate carriage to vertical position; release hand brake and remove monorail carriage from used SI module; pull used equipment tab at rack location		Monorail transfer system carriages and SI module in aft compartment and at stowage rack	
308.5	48.5						
		14.0	LST aft compartment worksite closeout after SI module replacement				
12.0	12.0	14.1	Assist CM2 to remove SI module monorail transfer system from LST aft compartment and transfer for stowage	Using tethers, disassemble/remove SI module monorail system (beginning at SI module stowage rack); stow system in equipment stowage rack		LST aft compartment; SI module and SSE equipment stowage rack; LST and Orbiter handrails	Assumes monorail transfer system not required on any subsequent EVAs

TABLE 2.4.5: LST EVA Task Completion Plans -- Mission Scenario No. 1 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: LST Scheduled Maintenance

Sheet 16 of 17

TIME (Min.)		SEQ.	FUNCTION AND CREW TASK			SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
CUM.	TASK		EVA CM1	EVA CM2	OTHER SUPPORT		
18.0	6.0	14.2	Inspect -V2 axis LST aft compartment access door seal; retrieve equipment tethers and attach to EMU; deactivate interior fixed lights; close and latch access doors	Continue SI module monorail transfer system disassembly, removal and stowage		LST handrails; LST -V2 axis aft compartment access door seal, closing and latch mechanisms; interior fixed light; switch EMU tether	Inspection assures acceptable stray light/contamination barrier
326.5	18.0						
		15.0	Portable light re[illegible]/stowage				
4.5	4.5	15.1	Translate to equipment stowage rack handrail; disconnect, remova portable lights (port and starboard ends of handrail) and transfer to CM2; ingress foot restraints at equipment stowage rack and assist CM2	Stow all hand tools in tool kit; accept portable light assemb'ies from CM1; stow lights. tethers and all EVA sup ort equipment		Orbiter payload bay door handrails; SSE equipment stowage rack	Stow and secure tools/equipment for reentry
331.0	4.5						

TABLE 2.4.5: LST EVA Task Completion Plans -- Mission Scenario No. 1 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: LST Scheduled Maintenance

Sheet 17 of 17

TIME (Min.) CUM.	TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	EVA CM2	OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
			16.0 LST stabilizing strut removal and EVA mission termination				
5.5	5.5	16.1	Egress foot restraints, translate and tether to starboard side of equipment rack handrail; notify Orbiter payload station crew clear for RMS engagement to LST; monitor operations	Egress foot restraints and join CM1, tether to handrail; monitor RMS engagement operations	Payload Station: Unstow RMS, engage and stabilize LST when crew clear of vehicle	SSE equipment storage rack handrails; RF voice communications	Strut removal performed if subsequent EVA operations are not planned
9.0	3.5	16.2	Translate to and ingress foot restraints at storage rack; remove stabilizing strut from between LST and storage rack	Return to storage rack and ingress foot restraints; assist CM1		LST (-V3 axis) aft station and SSE equipment storage rack; EMU tether	
13.5	4.5	16.3	Transfer stabilizing strut and stow in equipment storage rack; detach tether; secure all storage racks	Assist CM1; confirm all storage racks secure		Equipment storage racks	
17.0	3.5	16.4	Egress foot restraints, translate to airlock and ingress	Egress foot restraints, translate to airlock and ingress		Orbiter payload bay (doors and bulkhead) and airlock handrails	EVA OPERATIONS COMPLETE
348.0 TOTAL EVA TIME	17.0		TOTAL EVA TIME 5 hrs., 48 min.				

- Foot restraints (2 sets), tether attach points and mobility aids are provided at the equipment stowage racks.
- Sufficient lighting, fixed and/or portable, is provided by the Orbiter and payload to perform all extravehicular tasks.
- LST replacement equipment assemblies are provided and stowed in spare equipment racks located in the Orbiter payload bay.
- EVA support equipment items (i.e., portable workstation, equipment transfer/handling units, stabilizing strut, tethers and tools) are provided by the payload in stowage racks located in the Orbiter payload bay.
- Since design details were not available for LST equipment physical/functional interfaces and EVA support equipment (i.e., stowage racks, equipment transfer/handling units), conceptual designs were assumed to implement procedures development.

The LST EVA mission scenario no. 1 is predicated on the removal/replacement of equipment to retain and/or improve the spacecraft operating proficiency. Detail designs of the LST flight hardware items were not available and only limited preliminary conceptual design information was accessible on the space support equipment items. Therefore, to depict representative types of extravehicular operations and crewman interfaces that may be encountered, hardware concepts were either assumed or developed by the study. The hardware concepts are not intended to influence final component design.

In addition to the present Shuttle Orbiter EVA baseline accommodations, other support equipment will be required to accomplish the planned payload (scheduled) maintenance functions. These additional support items are discussed and summarized in Section 3.0 (Payload EVA Task Support Requirements) of this study.

2.4.4.3 LST EVA Mission Scenario No. 2 -- Retract Failed Solar Array Panel

The LST mission scenario no. 2 is based upon a primary task from the

"unscheduled EVA" category identified in Table 2.4.3. The hypothetical EVA mission was developed on the premise that a malfunction had occurred in the port solar array panel retraction mechanism. With the large 19.1 m^2 (206 ft^2) panel failed in the deployed position, it was considered a safety hazard to attempt RMS grapple, capture and berthing of the payload to the Orbiter. To capture and retrieve the LST, an EVA would be necessary to inspect/diagnose the failure and perform the operations necessary to retract/recinch the solar panel. Two EVA crewmembers, using the "EVA with MMU" operational mode, would be required. The primary tasks involved and task performance rationale are contained in Table 2.4.6.

2.4.4.4 LST EVA Task Completion Plans -- Mission Scenario No. 2

The LST task completion plans for mission scenario no. 2 provide a preliminary set of procedures and timelines which demonstrate that the selected EVA payload task can be accomplished by application of the Shuttle EVA system. The task completion plans identify principle elements of the EVA mission and the extravehicular mission support requirements including number of crewmen, EVA mission time, translation aids, restraints, tools and lighting.

The EVA task analysis preliminary timelines and procedures for the retraction of a deployed solar array panel (mission scenario no. 2) are provided in Table 2.4.7 and include identification of payload interfaces and support requirements. Assumptions associated with the mission scenario include the following:

- Two qualified Orbiter crewmembers are available for conducting an EVA. A third crewmember is available to perform Payload Station extravehicular supporting functions and crew activities monitoring.
- LST Mission Operations Center is available to perform diagnostic assistance, command telemetry functions and monitoring of LST systems.
- Sufficient crew mobility aids (i.e., handrails, handholds) are provided by the payload and/or Shuttle Orbiter to access the MMU flight support stations and support stowage areas from the airlock.

TABLE 2.4.6: LST EVA Tasks -- Mission Scenario No.2

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
RETRACT FAILED SOLAR ARRAY PANEL	Perform a two-man "unscheduled" EVA to retract solar array panel to allow Orbiter RMS grapple engagement for retrieval of LST from free space. Initial task is to diagnose failure and plan corrective operations	Assumes port (-V2 axis) solar array panel retraction mechanism malfunction leaving panel extended and preventing safe Orbiter RMS engagement for capture in free space.
1. FAILURE DIAGNOSIS	LST is in configuration for capture except for failed solar array panel. Orbiter RMS is stowed. Payload bay lights activated.	Note: Crewmen have obtained battery powered portable lights (one each) from Orbiter cabin stowage and tethered to EMU during EVA prep.
• Deploy Orbiter RMS/monitor	Activate RMS TV and lighting systems; deploy RMS to vicinity of LST failed solar panel retraction mechanism	Orbiter cabin payload station operations; provides lighting and safety video coverage during EVA operations outside payload bay
• Egress airlock and translate to MMU Flight Support Station (FSS)	Crewmen translation using handholds/handrails to MMU Flight Support Station	Requires crew mobility aids to MMU FSS's
• Don and checkout MMU's	Ingress MMU FSS; don and perform MMU checkout in preparation for EVA outside the Orbiter payload bay.	MMU's required for translation to/from worksites outside payload bay; two EV crewmen

TABLE 2.4.6: LST EVA Tasks -- Mission Scenario No.2 (Continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
• Translate to worksite	Crewmen translate to LST in vicinity of port (-V2 axis) solar array panel deploy/retract mechanism using MMU	MMU's used as mobility aid in free space, separate simultaneous operations by crewmen
• Inspect/diagnose and plan corrective action	Visually inspect solar array panel deploy/retract mechansim to determine cause of malfunction, corrective workplan, tools and ancillary support equipment; monitor retraction attempt as a trouble-shooting technique	Requires voice communication with LST Mission Operations Center (MOC) to activate mechanism actuator via command telemetry; crewman tether point and worksite access required
• Unstow tools and support equipment	Second crewman retrieve portable workstation and EVA support equipment from stowage rack	Requires portable workstation, tethers, handtools located in stowage racks in Orbiter payload bay
• Transfer support equipment to worksite	Second crewman returns to LST in vicinity of first crewman using MMU; hand carries workstation and support equipment to worksite	Equipment tethered to translating crewman
2. WORKSITE PREPARATION FOR SOLAR PANEL RETRACTION		
• Deploy portable workstation and equipment	Attach/deploy equipment and ingress portable workstation; activate workstation light to illuminate work area and deploy tool kit	Requires portable workstation interface or "Universal" attachment fixture

TABLE 2.4.6: LST EVA Tasks -- Mission Scenario No. 2 (Continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
3. SOLAR PANEL RETRACTION		
• Remove electrical connector	Disconnect and restrain electrical connector from deploy/retract actuator	Std. twist type electrical connector removed as safety precaution
• Remove deploy/retract actuator shaft coupling	Perform operations to remove deploy/retract actuator output shaft coupling	Two bolts in shaft coupling; output shaft must be disengaged since cannot back-drive actuator
• Retract solar array panel/monitor	Visually verify solar panel recinch mechanism latches are open; perform manual retraction of solar array panel; monitor retraction operation	Three latch interfaces on recinch mechanism; assumes retraction mechanism is operational, actuator only had failed
• Recinch solar panel/monitor	LST MOC command solar array panel recinching; monitor latching operation and verify recinch	Requires voice communication coordination with LST MOC; assumes recinching mechanism operational; EV crewmen remain in proximity until recinching achieved

TABLE 2.4.6: LST EVA Tasks -- Mission Scenario No.2 (Continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
4. <u>WORKSITE CLOSEOUT FOR SOLAR PANEL RETRACTION</u>		
• Remove portable work-station and support equipment	Remove all support equipment from worksite	Reverse of installation operations
• Stow tools and EVA support equipment	Crewmen return to payload bay and stow all EVA support items	Reverse of unstowing operations
• Monitor RMS engagement of payload	Observe RMS capture and stabilization of LST	Orbiter cabin payload station operations; EV crewmen observe operation from payload bay
• Return MMU to FSS	Translate to MMU FSS; doff, stow and recharge MMU, if required	Two EV crewmen perform separate simultaneous operations
• Translate to and ingress airlock		<u>TASK COMPLETE</u>

TABLE 2.4.7: LST EVA Task Completion Plans -- Mission Scenario No. 2

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Retract Failed Solar Array Panel MODE: EVA WITH MMU Sheet 1 of 6

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
		1.0	Prepare for unscheduled two-man EVA to inspect and retract malfunctioned port (-V2 axis) solar array panel for safe Orbiter RMS engagement/capture and retrieval of LST from free space			LST systems in capture configuration except for failed/extended solar array panel	Orbiter is station keeping with the LST at an approx. distance of 15.2m (50 ft)
5.0	5.0	1.1	Complete EVA preparation; retrieve battery powered portable light from airlock and tether to EMU	Complete EVA preparations; retrieve battery powered portable light from airlock stowage and tether to EMU	Payload Station: Activate payload bay lighting; activate RMS TV and lighting and maneuver RMS to vicinity of LST failed solar panel retraction mechanism	EMU tether; RMS, TV and lighting	Orbiter payload specialist monitors all EVA operations outside payload bay via payload station video; *2 battery powered portable light assemblies required
7.0	2.0	1.2	Egress airlock and translate to MMU Flight Support Station (FSS)	Egress airlock and translate to MMU FSS		Orbiter payload bay handrails	
32.0	25.0	1.3	Ingress FSS No.1; Don and checkout MMU; stow portable light for translation; perform trial flight	Ingress FSS No.2; Don and checkout MMU; stow portable light for translation; perform trial flight		MMU FSS	*MMU required for crewman translation outside payload bay in free space (2 required)
36.0	4.0	1.4	Translate to LST in vicinity of port (-V2 axis) solar array panel deployment/retraction mechanism and stabilize	Translate to LST in vicinity of port (-V2 axis) solar array panel deployment/retraction mechanism and stabilize on opposite side from CM1	Payload Station: Maintain RMS position constant during crewmen translation	MMU's; LST handrails	

* EVA support equipment required to complete LST Mission Scenario No.2 to be provided by payload

TABLE 2.4.7: LST EVA Task Completion Plans -- Mission Scenario No. 2 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Retract Failed Solar Array Panel

Sheet 2 of 6

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
48.0	12.0	1.5	Inspect solar array panel deploy/retract mechanism using portable light as required to illuminate area	Using portable light assist CM1 in inspection of solar array panel deploy/retract mechanism		Solar panel deploy/retract mechanism	Look for obvious damage to mechanism/actuator, mechanism misalignment, binding or interference
50.0	2.0	1.6	Translate clear of LST solar panel; notify LST Mission Operations Center (MOC) crew clear for panel retraction attempts; monitor and determine status	Translate clear of LST solar panel (opposite from CM1); monitor solar panel retraction attempts and determine status	LST MOC: Send telemetry command to retract solar array panel, repeat four times. Payload Station: Position RMS TV and lighting for video monitoring	RF voice communications LST command telemetry and solar panel retraction mechanism/actuator	Inspection has revealed panel is in correct attitude, articulation gimble lock-out mechanism is engaged correctly for retraction and no obvious damage, misalignment or binding exist in retract mechanism
54.0	4.0	1.7	Diagnose problem and formulate corrective work plan	Assist CM1 and determine tools/support equipment required			Failure of panel to retract indicates mechanism actuator has failed
57.0	3.0	1.8	Continue same as above	Translate to equipment stowage racks; ingress foot restraints	Payload Station: Maintain RMS position constant during crewman translation	MMU's, SSE equipment stowage racks in Orbiter payload bay	Foot restraints (2 sets) provided at stowage racks
62.5	5.5	1.9	Translate to worksite at failed solar panel retraction mechanism actuator, stabilize and attach tether	Retrieve portable workstation, carry-all container and 3 equipment tethers; tether and stow equipment for transfer and return to CM1 worksite		EMU tether; MMU	*Support equipment required o 1 portable workstation (with tool kit/hand tools and adjustable battery powered light) • Carry-all container • 3 equipment tethers
62.5	62.5						

* EVA support equipment required to complete LST Mission Scenario No.2 to be provided by payload

TABLE 2.4.7: LST EVA Task Completion Plans -- Mission Scenario No. 2 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Retract Failed Solar Array Panel

Sheet 3 of 6

TIME (Min.) CUM.	TASK	SEQ.	FUNCTION AND CREW TASK EVA CM1	EVA CM2	OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
		2.0	Worksite preparation for solar array panel manual retraction				
4.5	4.5	2.1	Deploy, attach and ingress portable workstation; activate and adjust workstation light; deploy tool kit and equipment tethers	Assist CM1 to set up workstation; transfer to opposite side of mechanism from CM1, stabilize and attach tethers		LST handrails and SSM equipment section exterior	Workstation light used to illuminate immediate work area; hand tool tethers provided as part of tool kit
7.0	2.5	2.2	Unstow, assemble and tether hand tools to workstation	Unstow and restrain carry-all container		EVA portable workstation	*Tools required: 3/8" drive rachet wrench, 4" extension socket, magnetic parts retainer and manual override adapter
69.5	7.0						
		3.0	Failed solar array panel manual override retraction				
1.5	1.5	3.1	Disconnect electrical connector from actuator	Assist CM1: restrain electrical connector when removed		Electrical connector housing	Std. twist type electrical connector removed for safety
11.5	10.0	3.2	Remove two bolts from deploy/retract actuator output shaft coupling; remove coupling from shaft	Assist CM1: tether output shaft coupling, capture bolts with magnetic retainer and stow bolts and coupling		Actuator output shaft coupling	Lock nuts are captive on coupling; output shaft disengaged to prevent back driving of actuator

* EVA support equipment required to complete LST Mission Scenario No.2 to be provided by payload

TABLE 2.4.7: LST EVA Task Completion Plans -- Mission Scenario No. 2 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Retract Failed Solar Array Panel

Sheet 4 of 6

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
20.5	9.0	3.3	Retract solar array panel	Verify solar array panel recinch mechanism latches (3) are open; assist CM1 and monitor retraction operation		Solar panel manual retract/deploy override; RF voice communications	Manual operation; override retraction mechanism is operational, actuator only has failed
24.0	3.5	3.6	Remove tool from solar array panel manual override; notify LST MDC crew ready for panel recinching; monitor latching operation and determine status	Assist CM1 in monitoring solar panel recinching operation and determine status	LST MDC: Send telemetry command to recinch solar array panel-confirm latching via telemetry talk-back	RF voice communications; LST command telemetry and solar panel recinching mechanism/actuator	Assumes recinching mechanism is operational; crewmen determine recinch latches have engaged panel
93.5	24.0						
		4.0	Solar panel worksite closeout, LST capture and EVA mission termination				
3.5	3.5	4.1	Stow all hand tools in tool kit, deactivate light on workstation; retrieve equipment tethers, egress workstation and detach from worksite; stow all support equipment for translation	Assist CM1: stow carry-all container and support equipment for transfer		EVA portable workstation; EMU tether	Recover all EVA support equipment for stowage

TABLE 2.4.7: LST EVA Task Completion Plans -- Mission Scenario No. 2 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Retract Failed Solar Array Panel

Sheet 5 of 6

TIME (Min.)		SEQ.	FUNCTION AND CREW TASK			SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
CUM.	TASK		EVA CM1	EVA CM2	OTHER SUPPORT		
7.5	4.0	4.2	Release tethers and translate to equipment stowage racks, stabilize and ingress foot restraints	Release tethers and translate to equipment stowage racks, stabilize and ingress foot restraints	Payload Station: Maintain RMS position constant during crewmen translation	MMUs and SSE equipment stowage racks	Crewmen return to Orbiter payload bay
12.0	4.5	4.3	Stow portable workstation and tethers in equipment stowage racks; secure stowage racks	Stow carry-all container (including removed bolts and coupling) and tethers in equipment stowage racks; confirm all stowage racks secure		SSE equipment stowage racks	Stow and secure support equipment for reentry; battery powered portable lights are returned to Orbiter cabin stowage
14.5	2.5	4.4	Egress foot restraints and translate to MMU FSS No.1	Egress foot restraints and translate to MMU FSS No.2	Payload Station: Maintain RMS position constant during crewman translation	MMUs	
19.5	5.0	4.5	Ingress FSS and monitor LST capture operations	Ingress FSS and monitor LST capture operations	Payload Station: Using RMS, capture and stabilize LST payload	MMU FSS	Payload retrieval, docking and berthing operations are not performed until crewmen ingress Orbiter airlock
49.5	30.0	4.6	Doff, recharge and stow MMU	Doff, recharge and stow MMU		MMU FSS	MMU recharge is dependent on any subsequent planned EVA operations

TABLE 2.4.7: LST EVA Task Completion Plans -- Mission Scenario No. 2 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Retract Failed Solar Array Panel

Sheet 6 of 6

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
53.0	3.5	4.7	Egress FSS, translate to and ingress airlock	Egress FSS, translate to and ingress airlock		Orbiter payload bay handrails	
63.0	10.0	4.8	Standby in airlock until LST is docked	Standby in airlock until LST is docked	Payload Station: Confirm LST berthed		EVA OPERATIONS COMPLETE
156.5 TOTAL EVA TIME	63.0						

TOTAL EVA TIME: 2 hrs., 37 min.

SPACE SHUTTLE EVA

- Realizing the potential requirement for an unscheduled EVA in free space, crew mobility aids and restraints (i.e., tether attach points, handholds, handrails) are provided by the payload.
- Foot restraints (2 sets), tether attach points and mobility aids are provided at the equipment stowage racks.
- Sufficient lighting is provided by the Orbiter and payload to perform all extravehicular tasks.
- RMS TV/lighting is available to support video monitoring of extravehicular crewmember activities in free space.
- EVA support equipment items (i.e., portable workstation, tethers and tools) and MMU's are payload-provided in stowage racks and flight support stations, respectively, located in the Orbiter payload bay.
- Since design details were not available for LST equipment physical/functional interfaces and EVA support equipment, conceptual designs were assumed or developed to implement procedures/timeline development.

EVA support equipment in addition to the present Shuttle Orbiter accommodations will be required to complete the unscheduled payload corrective action using the MMU. The additional support items are discussed and summarized in Section 3.0 (Payload EVA Task Support Requirements) of this study.

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2.5 SHUTTLE INFRARED TELESCOPE FACILITY (SIRTF)

2.5.1 SIRTF Program Desciption

2.5.1.1 Introduction

The Shuttle Infrared Telescope Facility (SIRTF) is one of a series of astronomy missions with the general objective of viewing the celestial sphere using an array of sensors designed to provide specific information concerning stellar and extended sources. The SIRTF mission objectives are: (1) to determine the physical processes, nature and structure of stars, galactic nebulae, interstellar matter, galaxies and other sources of infrared radiation in the 1-1000 μm wavelength region; (2) observe line emission in comets and planets; and (3) to experiment in the development of IR detector technology. The SIRTF relationship to other astronomy discipline objectives is to bridge the spectral region bounded by centimeter and millimeter wave length radio astronomy and by the optical ultraviolet X-ray observation. The SIRTF can observe short term phenomena in the radio and infrared regimes currently inaccessible to ground observations.

The 1-meter, liquid cryogenically-cooled IR telescope consists of a Cassegrain primary mirror with oscillating secondary cooled baffles, and a movable sun shield. The system accommodates six cooled instruments near the telescope focal plane. The six experiment objectives are listed in Table 2.5.1. A rotatable, tertiary coupling device directs the beam into the appropriate instrument. There is no direct focal plane access during operation. The SIRTF is optimized for the 5 to 200 μm spectral range.

2.5.1.2 SIRTF Payload Configuration

Phase B SIRTF studies were being conducted by the Hughes Aircraft Company concurrent to this EVA study. The SIRTF and supporting equipment characteristics, location in the Shuttle payload bay, and final equipment configurations were not available. This report selects concepts,

TABLE 2.5.1: SIRTF Experiments

TITLE	OBJECTIVE
Broad Band Filter Photometry, 10 to 1000 μm	To obtain accurate total luminosities of all types of galactic and extragalactic objects
Source Location and Flux Distribution, 5 to 100 μm	Unbiased survey to understand what kind of infrared objects exist; detail shape of the infrared flux distribution to obtain deviations from the smooth continuum
High Resolution Spectroscopy, 25 to 1000 μm	Determine velocity distribution in emission line sources; resolution: lambda/delta lambda = 50,000
Polarimetry, Linear and Circular	Obtain complex index of refraction and particle size of instellar matter; gather information on surfaces of planets, satellites, asteriods and dust clouds of comets
Intermediate Band Spectrophotometry, 50 to 100 μm	Accurate line profiles for planets, stars, instellar matter, galaxies, etc.; measurement of relative and absolute intensities of lines
Band Limited Spectrophotometry, 10 to 50 μm	Relative brightness measurements in selected IR bands

configurations, and supporting hardware locations based on Hughes data presented in July 1975 to the NASA Ames Research Center.

An SIRTF configuration and major supporting subsystem concept are shown in Figure 2.5-1. The major SIRTF pallet mounted systems located in the payload bay include the following:

- SIRTF telescope assembly
- Telescope gimbal/mounting system
- Control moment gyroscope attitude control subsystem
- Supercritical helium stowage tanks
- Water stowage tanks (Fuel cells)
- Telescope protective cover
- Electronic Equipment:
    - Electrical checkout and test units (6)
    - Guide star tracker
    - High speed multiplexer/demultiplexer units (2)
    - Telescope control electronics.

The SIRTF flight configuration, based on early 1976 documentation, will require a minimum of two payload pallets and will be flown on combined missions with other IR experiments.

2.5.1.3 SIRTF EVA Requirements

The SIRTF is being designed for operation from a payload station within the Orbiter cabin. No EVA is currently being planned, and only contingency extravehicular operations in the event of subsystem/component damage or malfunction. The possible EVA tasks associated with the SIRTF are categorized as unscheduled, contingency or potential planned as defined in Section 2.1.1 of this report. The SIRTF major systems are discussed in the following subsections to identify system components and operations which may benefit

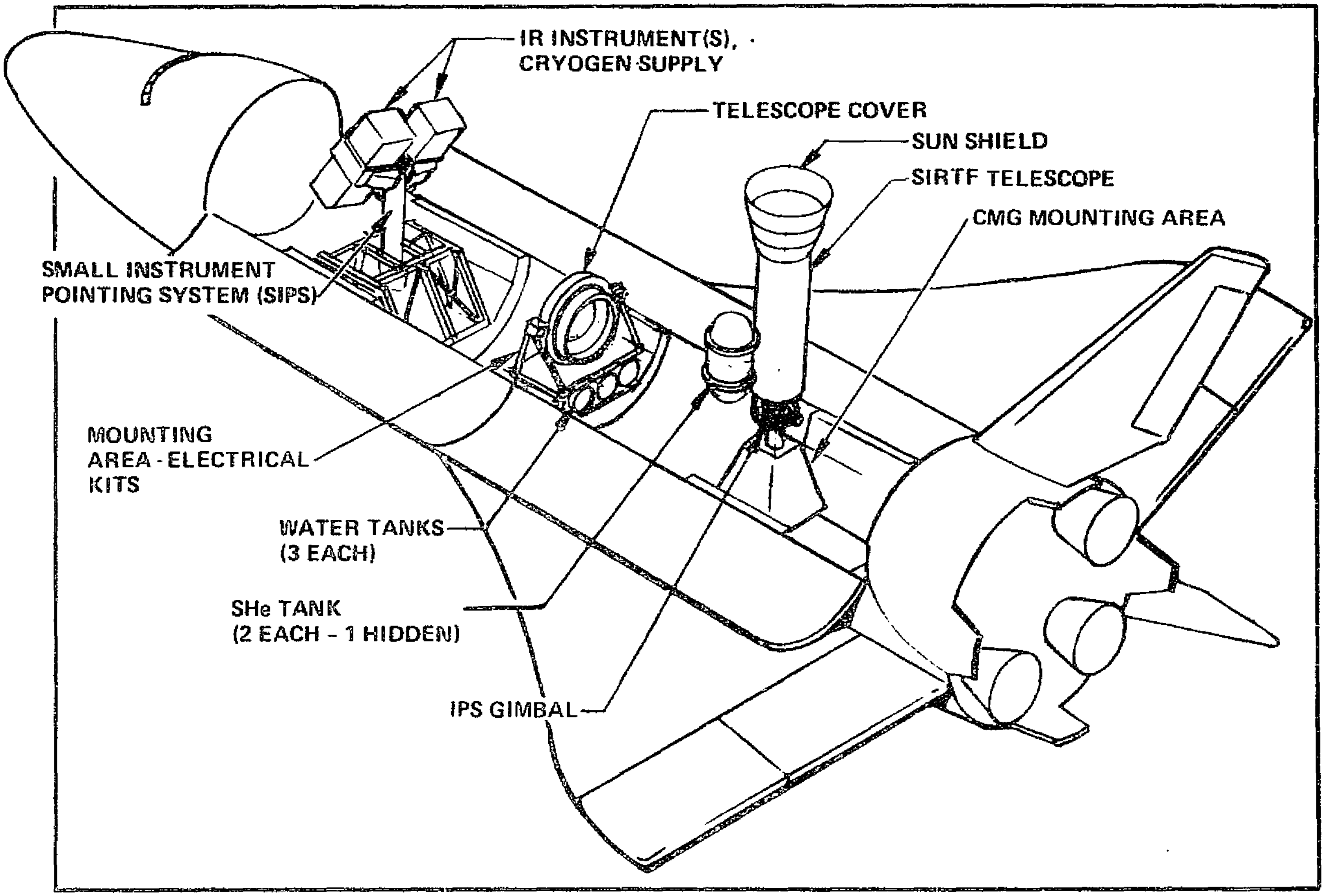

FIGURE 2.5-1: SIRTF Configuration and Support Systems Location (Concept)

from EVA capability should on-orbit problems occur. Since the SIRTF hardware design program is not scheduled for completion until early 1979, design details are limited.

2.5.2 SIRTF Payload Description

An SIRTF system block diagram is shown in Figure 2.5-2. The diagram depicts the SIRTF, Spacelab, and Orbiter associated hardware under study in early 1976.

2.5.2.1 SIRTF Telescope Assembly

The SIRTF telescope assembly is shown in Figure 2.5-3 with the sun shield retracted. The internal assembly precision design and alignment requirements preclude the need for on-orbit EVA interior access. The exterior of the telescope assembly incorporates subsystems such as sun shields, mechanical deployment devices, laser alignment components, insulation, etc. that may be candidates for EVA servicing/repair in an unscheduled or contingency EV mode.

The telescope assembly is approximately 729 cm. (23.8 ft.) in length and 174 cm. (5.7 ft.) in diameter with the sun shield deployed. The telescope sun shield (Figure 2.5-4) is approximately 236 cm. (7.7 ft.) long and 292 cm. (9.6 ft.) in diameter employing an externally mounted deployment linkage. Several instrumentation and alignment modules (black boxes) may be mounted on the telescope exterior which would permit EVA replacement or servicing on-orbit. A combination of both interior and exterior insulation is being studied for the telescope assembly. In the event of exterior insulation damage during launch or payload erection, EVA repairs could be effected to restore thermal integrity.

2.5.2.2 Telescope Gimbal/Mounting System

The SIRTF telescope gimbal and mounting system being studied consists of a European Instrument Pointing System (IPS) for telescope stabilization and

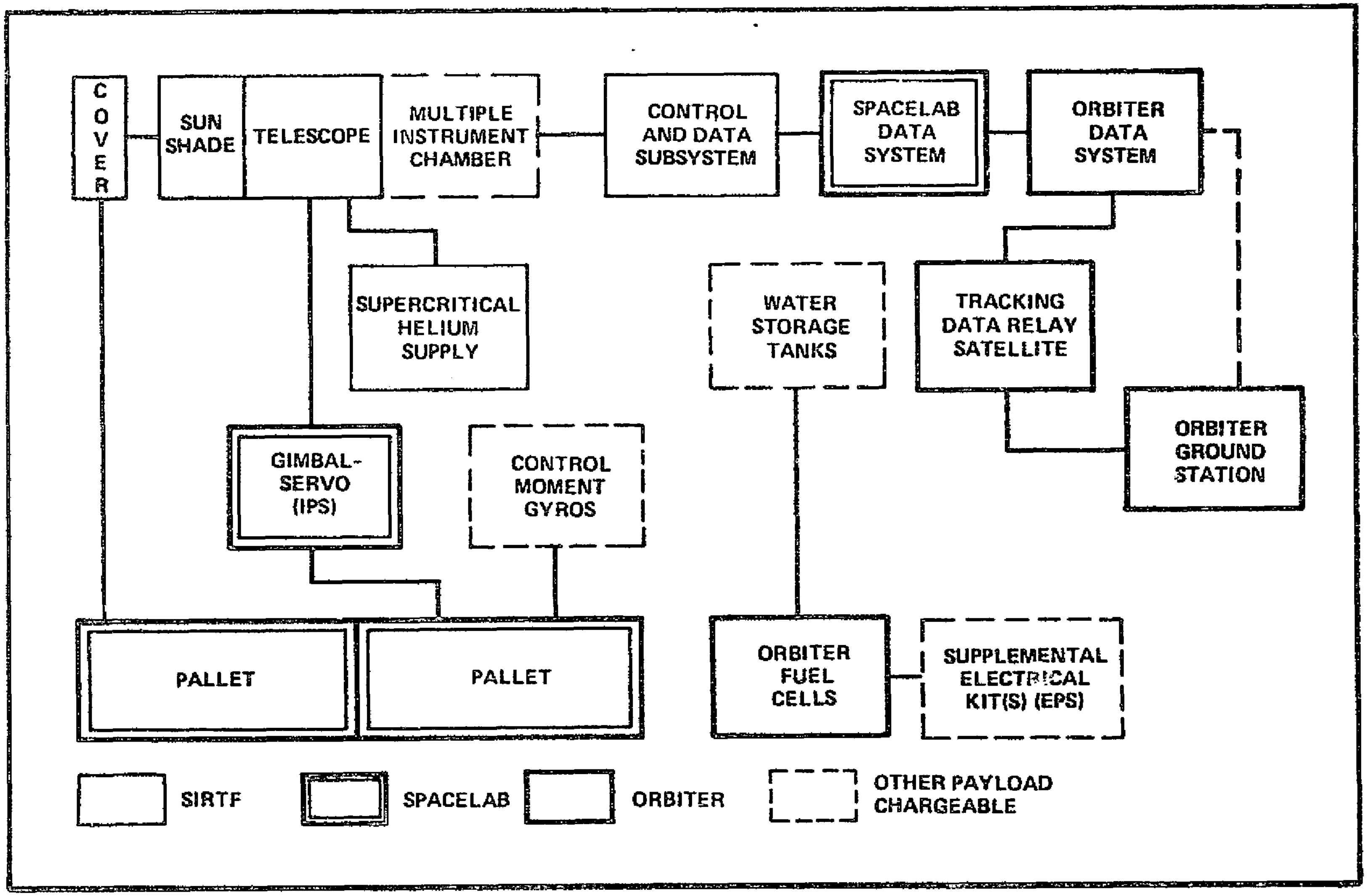

FIGURE 2.5-2: SIRTF System Block Diagram

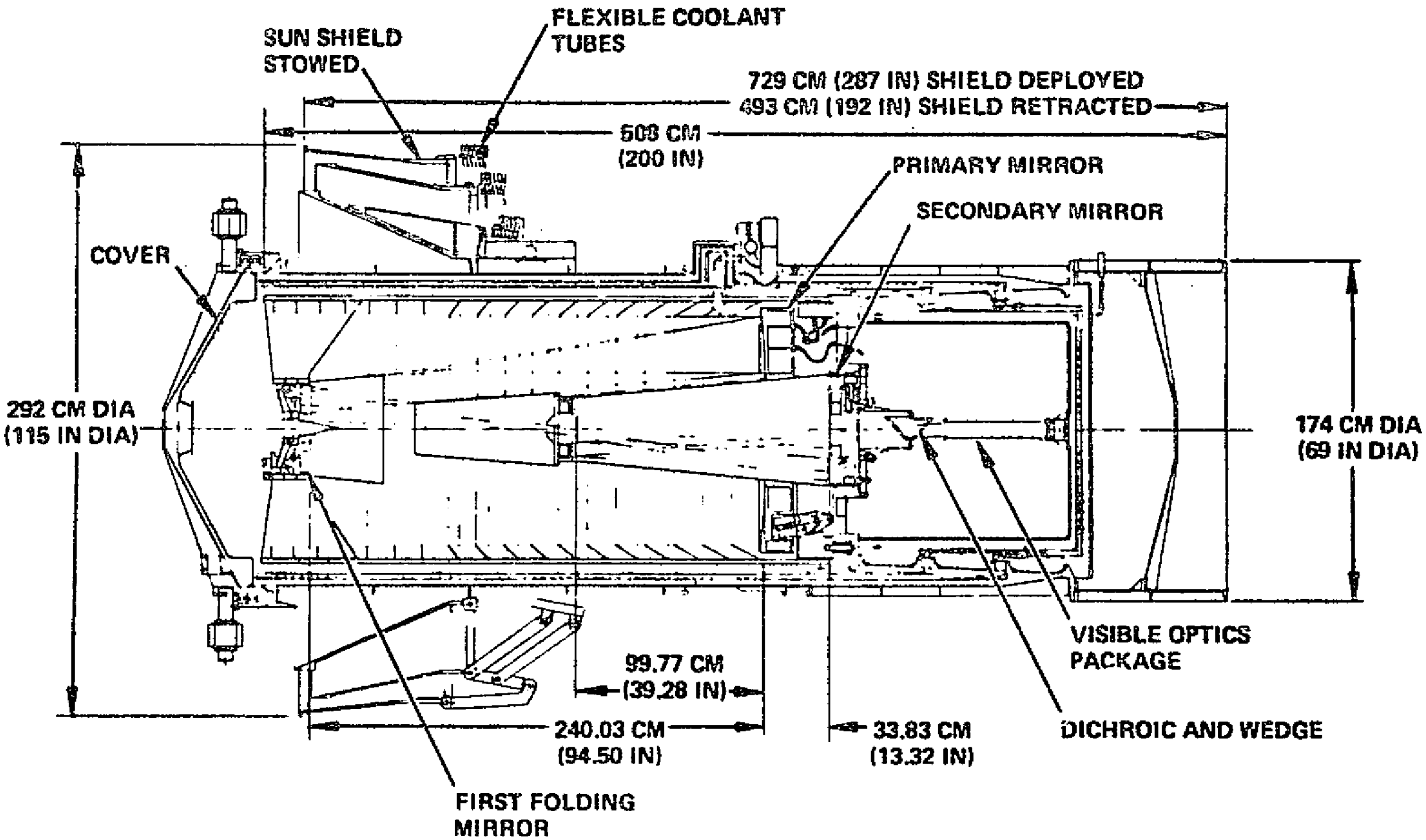

FIGURE 2.5-3: SIRTF Telescope Assembly -- Sun Shield Retracted

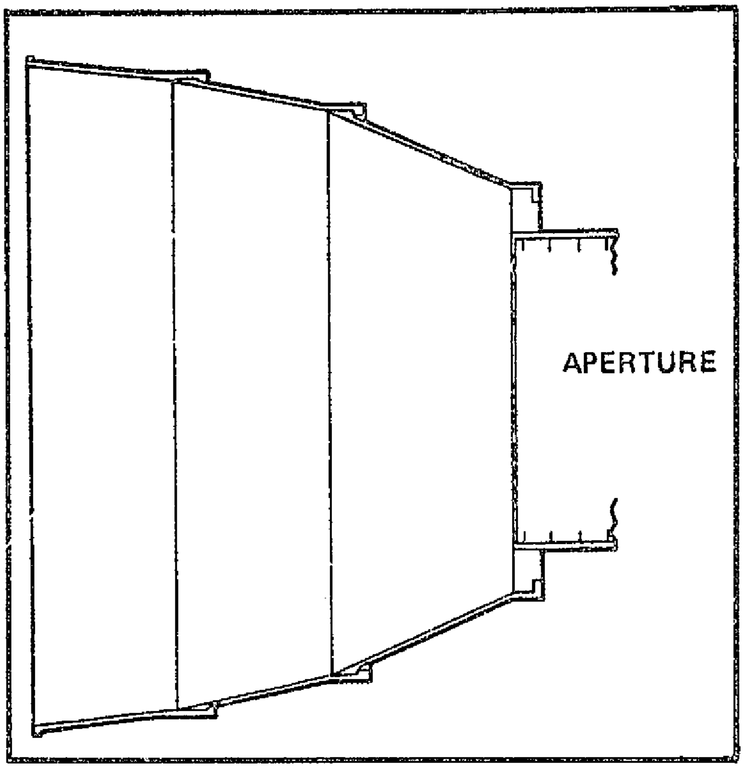

FIGURE 2.5-4: SIRTF Sun Shield Configuration

pointing. The IPS gimbals consist essentially of a universal joint mounted on a support structure, Figure 2.5-5. The support structure is then mounted on a standard Spacelab pallet. The telescope is supported at the aft end point. To avoid damage or misalignment to the gimbal bearings during launch, the telescope will be decoupled from the gimbals and supported along the entire length by structures within the bay. Angular travel about a pair of axes normal to the telescope line-of-sight is provided by the bearings of the universal joint. Capability for rolling the telescope about the line-of-sight is provided by rotation of the universal joint about the support structure. The gimbal base is soft-mounted to the structure to partially isolate the gimbals from base-motion disturbances.

The ring gimbal (the gimbal mounted on the support structure) is designated as azimuth and provides $\pm 180°$ angular travel (Figure 2.5-6). The inner gimbal is designated as cross-elevation and provides $\pm 60°$ angular travel. The outer telescope supporting gimbal is designated as elevation and provides $\pm 90°$ angular coverage (ref. Figure 2.5-6).

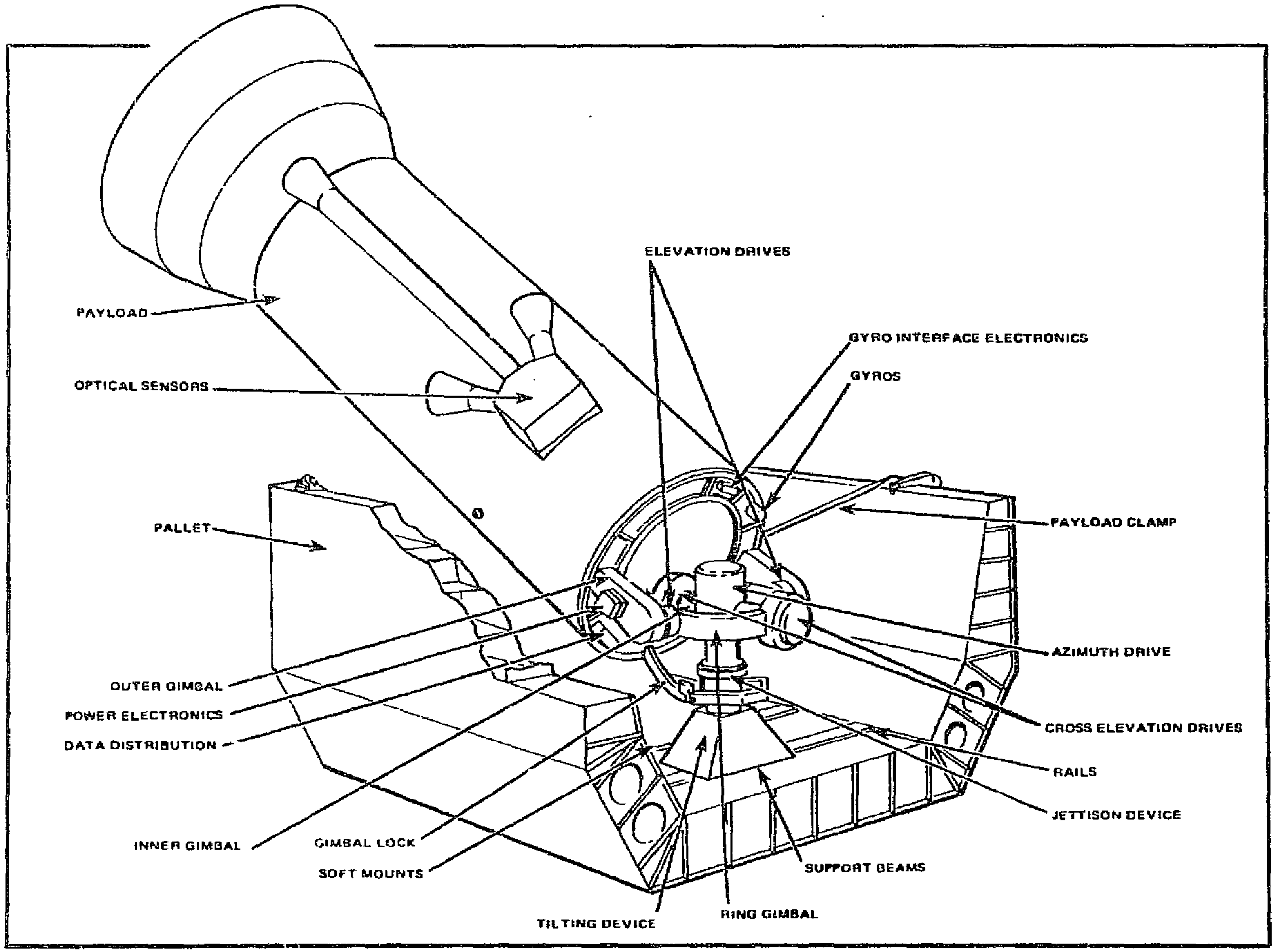

FIGURE 2.5-5: SIRTF Telescope Gimbal System

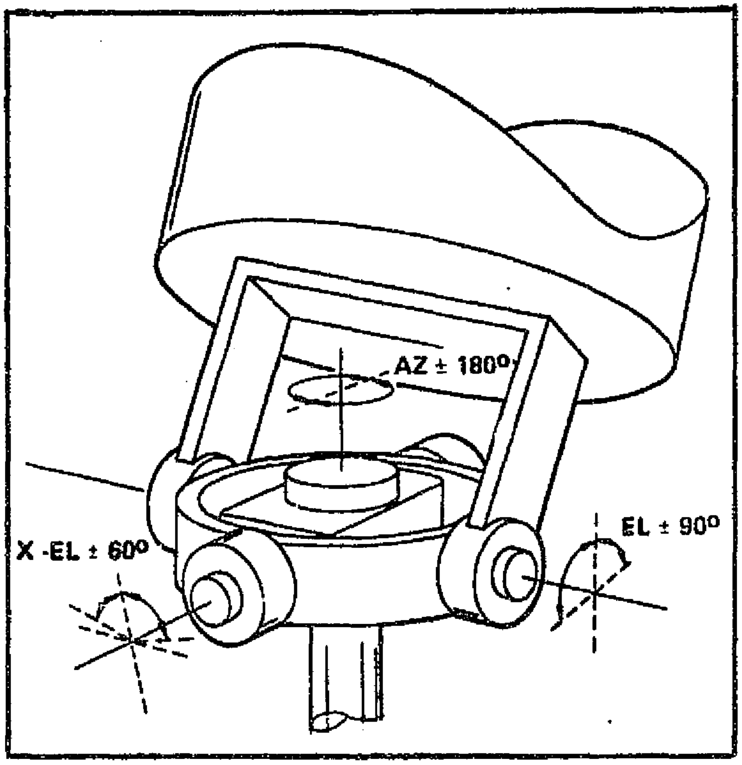

FIGURE 2.5-6: SIRTF Basic Gimbal System -- Angular Coverage

Mounted on or in the immediate vicinity of the gimbal system are stabilization gyroscopes, power and gyro interface electronics, data distribution boxes and various telescope support hardware. This category of equipment can be serviced or replaced if the system is designed for on-orbit maintenance. Additional equipment including gimbal locks, telescope tilting mechanisms, and jettison devices could utilize EVA in contingency situations (ref. Figure 2.5-5).

2.5.2.3 Control Moment Gyroscopes

A control moment gyro (CMG) attitude control subsystem is being studied for SIRTF stabilization. The gyro subsystem will consist of 4 single gimbal CMG's located on standard Spacelab pallets or platforms. The telescope will be slaved to the platform by means of the Instrument Pointing System (IPS) gimbal servo-mechanisms to stabilize the SIRTF to within 1 arc-second. The stabilization accuracy is further improved by using the platform gyro signals as inputs to autoalignment mirror servos. The com-

bination of IPS gimbals, the SIRTF stable platform, and the autoalignment system permit stabilization to within .25 arcsec.

The SIRTF platform CMG's (Figure 2.5-7) will be accessible by the EVA crewmembers based on early studies. Design permitting, the CMG's could be replaced on-orbit by EVA.

2.5.2.4 Cryogenic and Water Stowage Tanks

Cryogenic stowage tanks for supercritical helium are required for 2°K SIRTF cooling. One tank is required for 7-day Shuttle flights and two for 30-day missions. Tank locations are depicted in Figure 2.5-7. Each empty cryo tank weighs approximately 894 kg. (1970 lbs.) and provides a 210 kg. (465 lb.) cryo SHe supply.

Stowage tanks for fuel cell produced water are included in the SIRTF support hardware. Two tanks are required for a 7-day flight and four tanks to support a 30-day mission. Tank location relative to other SIRTF hardware is shown in Figure 2.5-7. Typical EVA applications may involve contingency operations to repair water tanks or associated plumbing to prevent telescope contamination.

2.5.2.5 Telescope Protective Cover

A protective cover is provided in the payload bay for damage and contamination protection prior to SIRTF orbital operations. Current concepts depict the protective cover and supporting assembly integrated into a dedicated SIRTF support structure (ref. Figure 2.5-7). Operation of the protective cover is designed as an automatic SIRTF function; however, design does not preclude manual contingency removal and replacement. The cover will be approximately 178 cm. (70 in.) in diameter.

2.5.2.6 Electronic/Support Equipment

It is anticipated that several "black box" SIRTF supporting assemblies will be mounted in the payload bay and accessible by EVA crewmen. The supporting

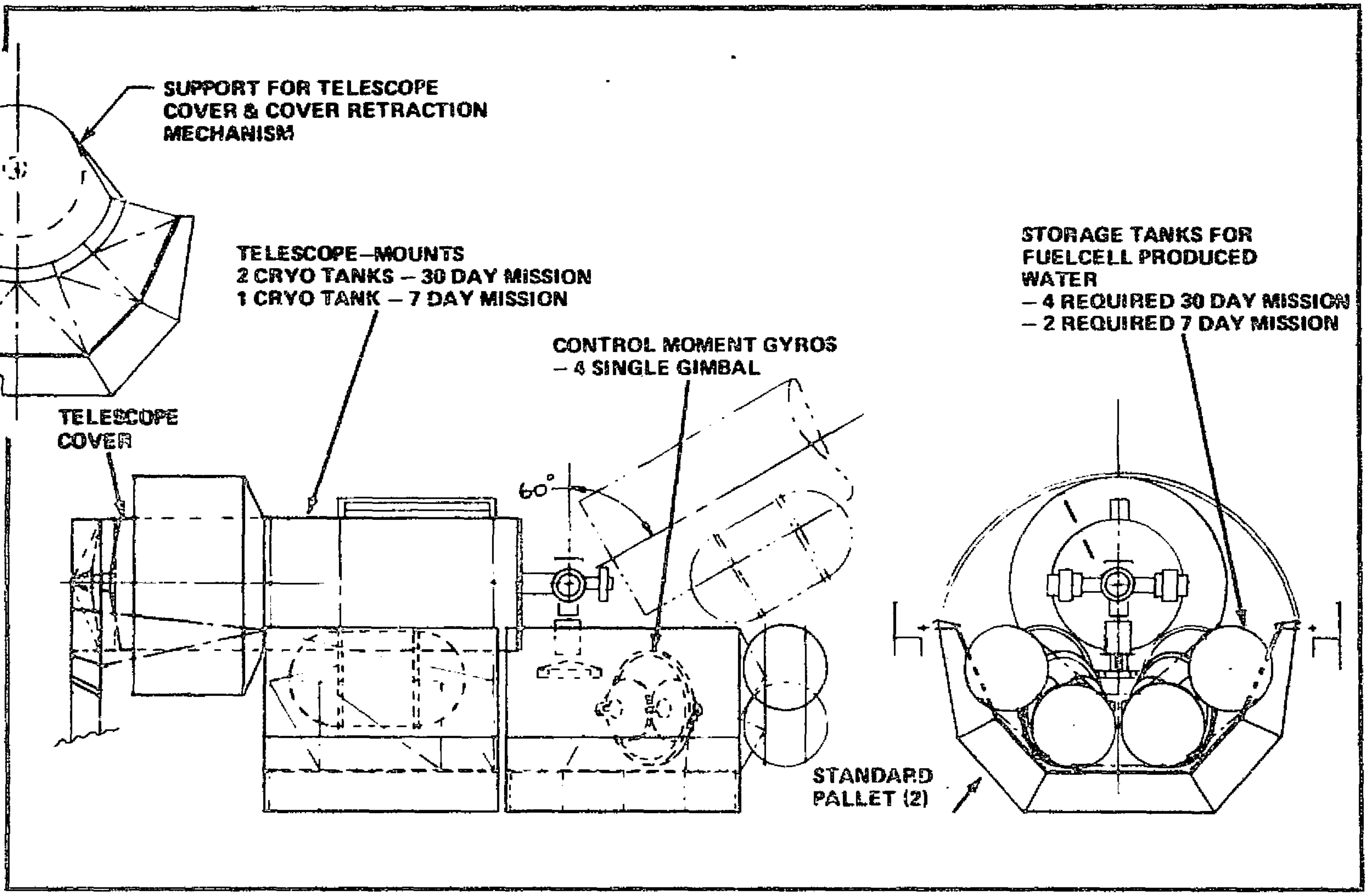

FIGURE 2.5-7: SIRTF Payload Bay Equipment Arrangement

assemblies may include electronic checkout and test units, star tracker subsystems, telescope control electronics, and cryogenic monitoring equipment. The quantity, physical characteristics or payload bay locations were not totally defined in the preliminary design studies terminating in late-1975. However, it is assumed that such externally mounted equipment critical to SIRTF operation will be designed for on-orbit replacement and/or servicing.

2.5.3 SIRTF EVA Task Selection

2.5.3.1 Planned EVA

The SIRTF preliminary design studies have indicated the facility to be totally operated from the Orbiter cabin using controls and automated features designed into the payload station. No planned EVA functions are identified in the early SIRTF design studies.

2.5.3.2 Unscheduled, Contingency and Potential Planned EVA

Payload damage or systems malfunction during launch or orbital operations may require EVA support to return the experiment to operational status, salvage equipment, or ensure safe vehicle and crew return. Under such conditions, an EVA mission could be conducted to perform corrective functions for experiment completion or configure/jettison equipment for safe flight termination. Typical EVA tasks are identified based on postulated anomalies and classified as unscheduled or contingency EVA in Table 2.5.2.

Since complete provisions are furnished by the Shuttle Orbiter to conduct two EVA's (two crewmembers) of 6 hours duration on each Shuttle flight, elimination of certain automated subsystems in the preliminary SIRTF design phase may be cost effective to the payload. Replacement of automated systems with manually actuated devices for EV crewman operations are suggested in the identification of potential planned EVA tasks in Table 2.5.2. The potential EVA tasks identified are based on the utilization of EVA and baseline EV support equipment to replace automated systems.

TABLE 2.5.2: SIRTF EVA Task Identification

UNSCHEDULED EVA	CONTINGENCY EVA	POTENTIAL PLANNED EVA
• Release/secure telescope hold-down clamp(s)	• Inspect/diagnose payload	• Payload Setup (Manual)
• Deploy/replace telescope front cover	• Remove debris/damaged hardware	- Remove telescope hold-down clamps(12)
• Remove/replace contamination shields	• Engage telescope hold-down clamps	- Remove and stow telescope front cover
• Release/secure gimbal locks	• Recouple gimbal system	- Remove and stow contamination shields
• Repair insulation (exterior)	• Remove telescope front cover from stowage and engage	- Couple gimbals to telescope
• Replace laser alignment source	• Vent cryo tanks	- Deploy sun shield
• Repair/remove sun shield linkage	• Remove/jettison H_2O tanks	- Mate instrumentation interfaces
• Deploy/retract sun shield	• Jettison telescope assembly (manually)	• Payload stowage
• Replace control moment gyro	• Direct RMS telescope jettison	- Reverse above operations
• Replace gyro interface electronics	• Configure SIRTF hardware for reentry following malfunction	
• Photo-TV coverage		

TABLE 2.5.2: SIRTF EVA Task Identification (continued)

UNSCHEDULED EVA	CONTINGENCY EVA	POTENTIAL PLANNED EVA
• Couple gimbals to telescope • Service/replace electronic support packages (black boxes)		

2.5.4 SIRTF EVA Mission Scenarios

The SIRTF primary source of information used in developing representive EVA mission scenarios was the preliminary SIRTF design study performed by the Hughes Aircraft Company. The SIRTF study was performed concurrent with this EVA applications study; the major objectives were as follows:

- Feasibility of a one meter class cooled infrared telescope for Shuttle application
- Development of preliminary SIRTF design
- Identification of technology requirements
- Estimation of performance and cost.

Since the SIRTF telescope and supporting systems were in the conceptual design phase, the operational subsystems, equipment and components configurations were obviously not available for study relative to EVA application. The preliminary SIRTF design, however, indicates all external operations will be remotely controlled from the Orbiter payload station. No planned EVA operations are presently identified.

Two EVA mission scenarios were developed from an analysis of the representative SIRTF tasks identified in Table 2.5.2. Several separate tasks were combined into a typical payload EVA mission based on the representative tasks. SIRTF EVA mission scenario number 1 assumes an electrical power failure to several telescope subsystems. The telescope, while being retracted into the reentry position, experiences a loss of power in the gimbal system and stops in the partially extended position. In order to close the Orbiter payload bay doors for reentry the telescope must either be jettisoned or an EVA mission conducted to salvage the SIRTF experiment equipment. Further visual observation indicates possible damage to the payload bay door closure mechanisms if jettisoned in the failed attitude. The EVA option is selected and is classified as a contingency operation. In order to configure the SIRTF for reentry a combination of manual and automated tasks must be performed. The crewman tasks consist primarily of

releasing the telescope gimbal system, retracting the sun shield, positioning the telescope, replacing the contamination cover, engaging the launch locks, etc. The major tasks involved and task performance rationale are provided in Table 2.5.3.

The second SIRTF EVA mission scenario is based on the payload being initially designed to employ manually actuated equipment and man-machine interfaces incorporated for conducting on-orbit EV experiment operations. The SIRTF design as currently conceived will use automated systems to actuate all latches, locks, deployment mechanisms, cover removal/stowage subsystems, etc. The potential planned EVA mission scenario assumes simple manual systems in lieu of the above. The major extravehicular operations would involve releasing launch lock mechanisms, removing contamination covers and manually deploying experiment systems at experiment initiation and reconfiguring the experiment hardware for reentry. The primary tasks for the SIRTF mission scenario no. 2 are listed, and task performance rationale provided in Table 2.5.4.

2.5.5 SIRTF EVA Task Completion Plans--Mission Scenario No. 1

The SIRTF EVA task completion plans are designed to provide a preliminary set of crew procedures and timelines depicting the major sequential steps in accomplishing the payload servicing requirements. The task completion plans delineate the major elements of the EVA mission and the extravehicular mission support requirements including the number of crewmen, EVA mission time, restraints, tools, translation aids, safety tethers and other ancillary equipment.

The preliminary timelines and procedures developed for the SIRTF mission scenario no. 1 (contingency EVA to retract and stow the telescope for reentry) are contained in Table 2.5.5. The following assumptions relative to Orbiter and payload EVA accommodations and mission scenario task performance are listed below:

TABLE 2.5.3: SIRTF EVA Tasks -- Mission Scenario No. 1

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
RETRACT AND CONFIGURE SIRTF FOR REENTRY	Perform a two-man contingency EVA to stow SIRTF payload for reentry	Malfunction in SIRTF power system resulting in only partial retraction of telescope
• Egress airlock and translate to telescope	Crew translation using payload bay handrails	Use existing mobility aids
• Inspect and diagnose	Determine approach to telescope stowage	May require use of payload structures as crew translation aids
• Translate to tool stowage	Retrieve equipment tethers, tools and portable EVA foot restraints	Stowage locker located in payload bay
• Transfer repair equipment to worksite	Hand carry repair equipment	Tethering equipment to crewman
• Deploy and ingress EVA workstation	Attach workstation to Orbiter or payload structure	Requires workstation interface or "universal" attachment fixture
• Attach equipment tethers to telescope	Attach tethers to aperture end of telescope	Required to control telescope during positioning
• Position telescope	Retract telescope to stowage cradle	Requires gimbal system drive release or "backdrive" units
• Retract sun shield	Position sun shield for telescope stowage	Must be retracted for stowage

TABLE 2.5.3: SIRTF EVA Tasks -- Mission Scenario No. 1 (continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
• Replace contamination cover	Position cover for telescope stowage	Cover subsystems incorporate launch lock devices
• Configure subsystems for reentry and landing	Position restraint/locking devices to prevent telescope systems damage	Includes gimbal mount, thermal isolators, gyros, mirrors, sun shield, etc.
• Secure telescope launch support latches	Engage intermediate and front support arm securing units	Secures telescope for re-entry
• Ingress airlock		MISSION COMPLETE

TABLE 2.5.4: SIRTF EVA Tasks ---Mission Scenario No. 2

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
SIRTF PAYLOAD ON-ORBIT SETUP (MANUAL)	Perform a two-man (potential planned) EVA to configure payload for on-orbit operation	Manual design should be economical in payload development and number of launch programs
o Egress airlock and translate to tool stowage	Translate using Orbiter and payload provided handrails	Access provisions incorporated in design
o Retrieve dedicated tool kit and restraints	Ingress foot restraints, open stowage container and retrieve tools	Requires standard tools only
o Translate to gimbal end of telescope	Hand carry tools and equipment to worksites and attach foot restraints	Tether equipment to spacesuit
o Retract thermal isolators	Insert tool and actuate isolator mechanisms	Cryogenic jacket is secured by thermal insulators during launch and are decoupled for operation
o Uncage Instrument Pointing System (IPS) gyros and mirrors	Engage tool and uncage gyros	Gyroscopes are caged when not operating
o Release IPS launch locks	Manually release IPS launch locks	No tools required
o Release intermediate telescope support latches	Manually release intermediate support/launch latches	
o Deploy sun shield	Release latches and deploy sun shield	No tools required

TABLE 2.5.4: SIRTF EVA Tasks -- Mission Scenario No. 2 (continued)

TASK/ACTIVITY	OPERATIONS OVERVIEW	RATIONALE/REMARKS
• Attach EMU contamination collector to EMU	Attached by second EV crewman	Retains H_2O vapor for TBD min.
• Remove contamination cover and stow	Release latches, remove and stow	Time limited operation to avoid contamination
• Release front support locks	Manually release latches on front of telescope	Time limited operation
• Deploy telescope to intermediate position	Deploy telescope free of stowage rack restraints into the intermediate position	Time limited operation
• Ingress airlock		MISSION COMPLETE

SPACE SHUTTLE EVA

- Only partial electrical power to the payload is lost.
- Adequate crew mobility aids are provided by the Orbiter to inspect the payload.
- Structural equipment and hardware protrusions on the payload and pallets (and in payload bay) provide sufficient mobility aids for crew access to required payload areas.
- Standard Shuttle tool kit contains the necessary equipment for task completion.
- Two qualified crewmembers are available for conducting EVA.
- Capability exists to manually disengage drive systems, release clutches/brakes or backdrive the subsystems necessary to effect telescope stowage.
- Provisions for manually engaging the launch lock mechanisms are incorporated into the unit design.
- Sufficient lighting is provided by the Orbiter to perform the EV tasks.
- Foot restraints (1 pair) and mobility aids are provided at the tool stowage locker.
- No spare parts or special tools are available for payload servicing.

Detail design of SIRTF equipment/subsystems that may require an EV man-machine interface to complete mission scenario no. 1 was not available during this study. Only overall conceptual layouts of the major components were available from the SIRTF preliminary design study contractor (Hughes Aircraft Company). In performing the tasks included in the EVA mission scenario it was assumed that the operational hardware subsystems and man-machine interfaces encountered would be compatible in design to "typical" Shuttle payload subsystems.

The mission scenario is performed with basic hand tools from Shuttle on-board stowage -- no additional EVA support equipment is required. The SIRTF EVA mission scenario no. 1 preliminary timelines and procedures are provided in Table 2.5.5.

2.5.6 SIRTF EVA Task Completion Plans -- Mission Scenario No. 2

The second SIRTF EVA mission scenario is based on the payload being designed for manual on-orbit release and configuring at experiment initiation and stowing prior to reentry. The payload automated launch locks, contamination covers, retraction devices, equipment caging units, gimbal locks, etc., would be replaced with manually operated mechanisms. The payload subsystems would provide man-machine interfaces for either manual unassisted operation or interfaces for "standard" tools. The hypothetical EVA mission operations release the payload from the launch configuration, actuate all externally accessible mechanical subsystems required to effect operational status and assists initial telescope erection.

The primary EVA tasks selected for SIRTF mission scenario no. 2 are outlined in Table 2.5.4 including EVA task performance rationale. The EVA task completion plans, shown in Table 2.5.6, provide a preliminary set of time-lines and procedures to configure the payload for orbital operation. The reverse procedure would be used at experiment completion. Assumptions and guidelines associated with the mission scenario include the following:

- The SIRTF mechanical subsystems are specifically designed for on-orbit EV operation and servicing.
- Only manually actuated devices and standard mechanics hand tools will be used to perform the SIRTF tasks.
- Crew translation aids are provided at all required locations by the payload.
- A set of portable foot restraints for each crewman and foot restraint ingress aids are provided by the payload.

TABLE 2.5.5: SIRTF Task Completion Plans -- Mission Scenario No. 1

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Retract And Configure SIRTF For Reentry MODE: UNAIDED EVA Sheet 1 of 7

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
		1.0	Prepare for contingency two-man EVA to retract SIRTF telescope to permit payload bay door closure and stow/configure payload for reentry and landing				
4.5	4.5	1.1	Egress airlock and translate to telescope gimbal; tether and stabilize	Egress airlock and translate to telescope forward end and stabilize	Payload Station: Payload bay lighting as required	Airlock exterior, payload bay handrails	Only Orbiter-provided EVA accommodations are available
19.5	15.0	1.2	Inspect telescope equipment and diagnose problem; examine electrical cable/connectors	Formulate approach for manually retracting telescope		Payload structures	
21.0	1.5	1.3	Translate to tool stowage and ingress foot restraints	Translate to tool stowage and stabilize		Tool stowage container; foot restraints	
24.0	3.0	1.4	Retrieve tools, equipment tethers and egress foot restraints	Secure tools and equipment tethers to spacesuit (use carry-all bag)			Equipment required: o 3/8" drive ratchet and extension o Pry bar o Combination open/box end wrench set o 6 equipment tethers
25.5	1.5	1.5	Remove foot restraints and tether to spacesuit	Translate to telescope gimbal mount			Foot restraints used in telescope retrieval

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TABLE 2.5.5: SIRTF Task Completion Plans -- Mission Scenario No. 1 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Retract And Configure SIRTF For Reentry

Sheet 2 of 7

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
28.5 / 28.5	3.0 / 28.5	1.6	Translate to telescope gimbal mount and attach foot restraints	Remove tools and tether tools to payload		Payload structures and subsystems	
		2.0	Telescope gimbal drive release and payload retraction				
4.0	4.0	2.1	Ingress foot restraints, retrieve tools and determine method of releasing gimbal	Prepare to translate along telescope to attach tethers	Payload Station: Observe EV crewman operations		EVA CM2 must translate over exterior of telescope to sun shield area and attach tethers
16.0	12.0	2.2	Egress foot restraints and manage CM2's tether during translation	Translate over telescope exterior to sun shield		Telescope exterior structures	Use telescope structures for mobility aids
20.0	4.0	2.3	Manage CM2's safety tether	Attach equipment tethers (2) to telescope structure; attach second tether hook to spacesuit		Sun shield	Attach tethers ≈ 90° apart if possible near sun shield
21.0	1.0	2.4	Pull CM2's safety tether taut and guide "free-floating" crewman to payload bay	Crewman release payload and translate to payload bay with equipment tethers attached; stabilize		Payload bay translation aids	CM2 is tethered with three tethers SAFETY NOTE: Use extreme caution in crewman translation from telescope to payload bay. Crewman CM2 is in a semi-free-floating mode (with tethers attached) for approx. 3.7 m. (12 ft.)

TABLE 2.5.5: SIRTF Task Completion Plans -- Mission Scenario No. 1 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Retract And Configure SIRTF For Reentry

Sheet 3 of 7

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
27.0	6.0	2.5	Translate to gimbal end of telescope, release gimbal and retrieve foot restraints	Attach one equipment tether to payload bay port side and translate with second tether to forward end of telescope stowage rack		Gimbal subsystem	Use 3/8" drive ratchet and extension to release gimbal
32.0	5.0	2.6	Translate to forward end of telescope stowage rack and attach foot restraints	Ingress foot restraints and initiate telescope movement using tether			SAFETY NOTE: Move telescope extremely slow to avoid momentum buildup and stand clear of telescope path
50.0	18.0	2.7	Translate to port side tether and stabilize; assist CM2 in "guiding" telescope	Retract telescope into stowage rack and secure tether to structure			SEE FIGURE 2.5-8
78.5	50.0						
		3.0	Replace contamination cover				
8.0	8.0	3.1	Assist CM2; retrieve tethers and place in carry-all bag	Replace telescope front contamination cover and engage telescope latches		Contamination cover subsystem	Telescope front launch locks are incorporated into contamination cover subsystem
12.0	4.0	3.2	Lock telescope front latches using 9/16" box end wrench	Remove foot restraints and translate to gimbal end of telescope		Telescope front latches	Use standard box end wrench to secure telescope front launch locks

TABLE 2.5.5: SIRTF Task Completion Plans -- Mission Scenario No. 1 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Retract And Configure SIRTF For Reentry

Sheet 4 of 7

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
22.0 / 100.5	10.0 / 22.0	3.3	Translate to gimbal area; Inspect telescope exterior in route	Attach foot restraints at gimbal area; Inspect telescope subsystems			Check for indications of electrical malfunction
		4.0	Configure subsystems for reentry and landing				
4.0	4.0	4.1	Ingress foot restraints; acquire tools for locking gimbals	Continue telescope sub-systems inspection; Assist CM1		Telescope structure	
9.0	5.0	4.2	Lock gimbal mount system	Assist CM1			Use 3/8" drive ratchet and extension
10.0	1.0	4.3	Standby for automatic caging of pointing system gyros and telescope mirrors	Standby	Payload Station: cage gyros and mirrors (switch actuation)	Payload bay handrails	Electrical power to sub-systems was not interrupted
11.0	1.0	4.4	Confirm subsystems were actuated	Assist CM1	Payload Station: confirm indicators depict locked status		Visually observe lock position and/or indicator SAFETY NOTE: EVA crewman translates to area clear of telescope operational envelope when observing any automatic experiment function.

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TABLE 2.5.5: SIRTF Task Completion Plans -- Mission Scenario No. 1 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Retract And Configure SIRTF For Reentry

Sheet 5 of 7

TIME (Min.)		SEQ.	FUNCTION AND CREW TASK			SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
CUM.	TASK		EVA CM1	EVA CM2	OTHER SUPPORT		
17.5	6.5	4.5	Couple/engage thermal isolators for reentry	Assist CM1		Gimbal/telescope mounted subsystems	Manually drive thermal isolators using 3/8" drive ratchet and extension
19.0	1.5	4.6	Standby for isolator coupling confirmation	Standby	Payload Station: confirm indicators show coupled status		
21.5	2.5	4.7	Translate to port side telescope intermediate support/launch lock; stabilize	Translate to port side telescope intermediate support/launch locks			Use payload bay handrails, telescope exterior and stowage rack for translation
26.5	5.0	4.8	Engage intermediate launch lock	Assist in stabilizing CM1 during launch lock actuation			Use pry bar to engage launch lock (interface incorporated in initial design)
29.5	3.0	4.9	Translate to starboard side telescope intermediate support/launch lock; stabilize	Translate to starboard side		Telescope exterior and stowage rack	To conserve time, only a crew tether and the CM2 crewman are used to stabilize CM1 during intermediate launch lock engagement. Design of the launch lock assumes foot restraints will not be required.

TABLE 2.5.5: SIRTF Task Completion Plans -- Mission Scenario No. 1 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Retract And Configure SIRTF For Reentry

Sheet 6 of 7

TIME (Min.) CUM.	TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	EVA CM2	OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
34.5	5.0	4.10	Engage intermediate launch lock	Assist in stabilizing CM1 during launch lock actuation			Use pry bar to engage launch lock
36.0	1.5	4.11	Translate to gimbal end of telescope	Translate to gimbal end of telescope			
42.0	6.0	4.12	Standby for systems status check	Standby	Payload Station: Readout status of reentry configuration		Payload Station provides readback status of functioning telescope subsystems
142.5	42.0						
		5.0	Prepare for and terminate EVA mission				
2.5	2.5	5.1	Ingress foot restraints and retrieve tools	Assist CM1			Use carry-all bag for tool transport
4.5	2.0	5.2	Egress foot restraints and translate to tool stowage	Detach foot restraints and translate to tool stowage		Payload bay handrails, tool stowage container, foot restraint stowage and tool stowage interface	CM 1 assists CM2 stabilization during foot restraint detachment. Foot restraints are replaced at initial location outside tool/equipment stowage container. Both crewmen maintain tether attachment to structure during all EVA operations.

TABLE 2.5.5: SIRTF Task Completion Plans -- Mission Scenario No. 1 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: Retract And Configure SIRTF For Reentry

Sheet 7 of 7

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
9.0	4.5	5.3	Ingress foot restraints; stow tools	Attach foot restraints at tool stowage container; Assist CM1			Stow and secure tools for reentry
13.0	4.0	5.4	Egress foot restraints, translate to airlock and ingress	Translate to airlock and ingress			EVA OPERATIONS COMPLETE
155.5 TOTAL EVA TIME	13.0						

TOTAL EVA TIME: 2 hrs., 36 min.

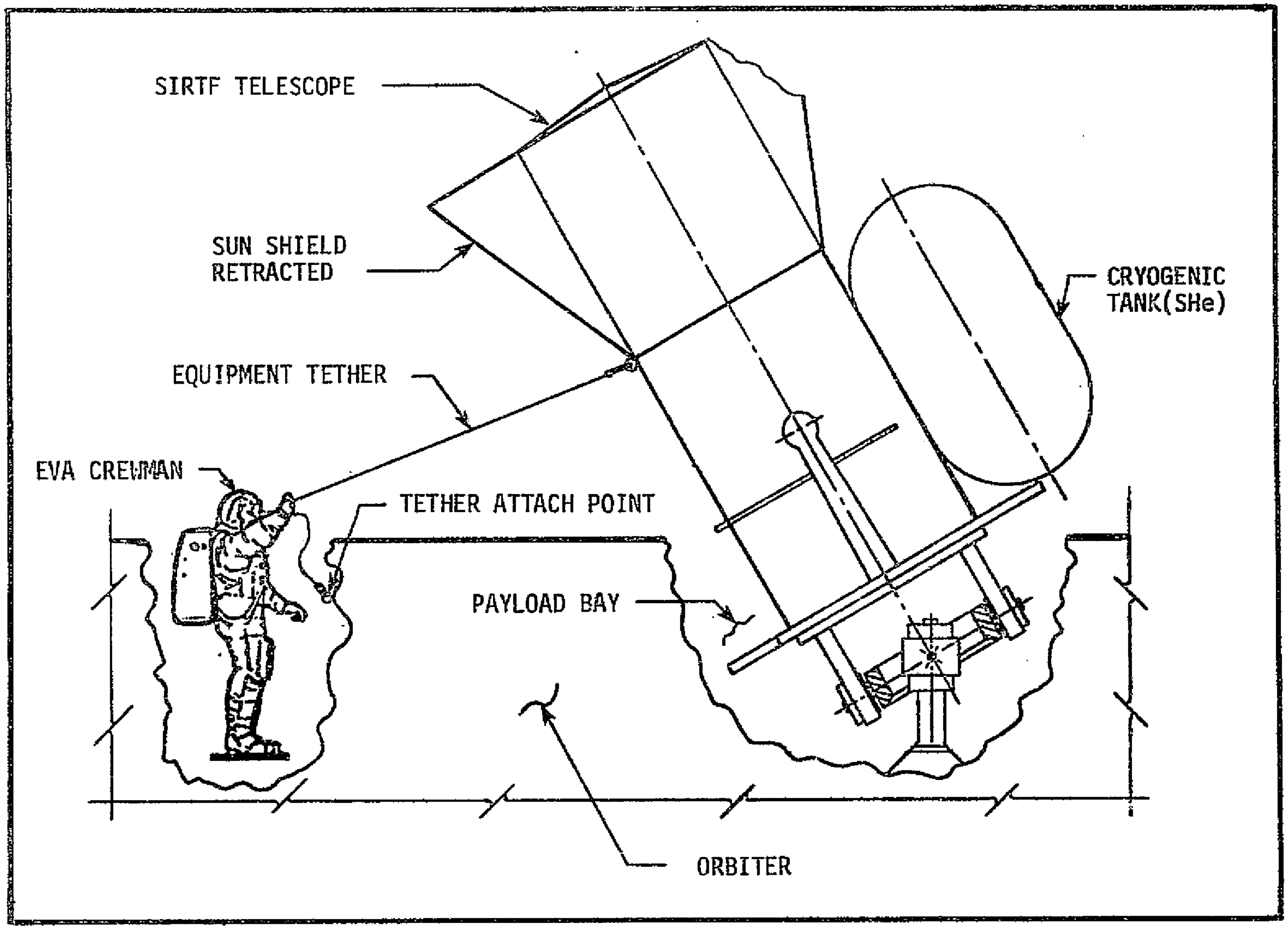

FIGURE 2.5-8: Contingency EVA SIRTF Telescope Retrieval

TABLE 2.5.6: SIRTF Task Completion Plans -- Mission Scenario No. 2

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: SIRTF Payload On-Orbit Setup (Manual) MODE: UNAIDED EVA Sheet 1 of 5

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
		1.0	Prepare for two-man EVA to configure the SIRTF for on-orbit operation				
3.5	3.5	1.1	Egress airlock and translate to tool stowage container; ingress foot restraints	Egress airlock and translate to tool stowage	Payload Station: observe EV crewman operations	Orbiter handrail system	Stowage container located on pallet; foot restraints provided by payload
7.5	4.0	1.2	Retrieve tools and equipment from stowage; egress foot restraints	Retrieve portable EVA foot restraints; tether to spacesuit; translate to gimbal end and attach foot restraints			Tool caddy contains only standard tools from Shuttle tool list
10.0	2.5	1.3	Translate to gimbal end of telescope; ingress foot restraints	Translate to intermediate payload support/launch lock (port side) location; attach crew tether		Payload handrail system and payload structure	*Requires approx. 9.2 m. (30 ft.) EVA handrail
10.0	10.0						
		2.0	Release telescope launch lock and operational subsystems				Foot restraint attach provisions (passive) are designed into payload at each worksite
4.5	4.5	2.1	Decouple telescope thermal isolators; confirm actuation	Release telescope port side intermediate launch lock (leave safety latch attached)	Payload Station: observe EV crewman operations	Payload support structure; manual latches	Retracts cryogenic elements secured by thermal isolators for launch. Launch lock actuation requires 3/8" drive ratchet.

*EVA items/equipment required to complete SIRTF mission scenario no. 2 to be provided by payload.

TABLE 2.5.6: SIRTF Task Completion Plans -- Mission Scenario No. 2 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: SIRTF Payload On-Orbit Setup (Manual)   Sheet 2 of 5

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
8.5	4.0	2.2	Uncage Instrument Pointing System (IPS) gyroscopes	Translate to telescope starboard side intermediate launch lock location; attach crew tether		Payload support structure; tools	Releases IPS gyros; use 3/8" drive ratchet and extension
13.0	4.5	2.3	Uncage telescope mirrors	Same as above			Manually retract mirror caging mechanism; use 3/8" drive ratchet and extension
17.5	4.5	2.4	Release IPS launch locks	Release telescope starboard side intermediate launch lock (leave safety latch attached)			
20.0	2.5	2.5	Stow tools in caddy; egress foot restraints; detach tether	Translate to gimbal end of telescope; retrieve foot restraints			
30.0	20.0						
			3.0 Remove contamination cover and stow				
3.5	3.5	3.1	Translate to tool stowage locker; ingress foot restraints	Translate to sun shield area; attach foot restraints and ingress (port side)		Orbiter and payload bay translation aids	Attach foot restraints on port side of payload support cradle
7.5	4.0	3.2	Stow tools and retrieve EMU contamination collectors	Release contamination cover/ front telescope support			*Two contamination collectors required to prevent payload contamination

*Required to avoid contaminating payload; payload chargeable. REQUIRES FEASIBILITY STUDY.

TABLE 2.5.6: SIRTF Task Completion Plans -- Mission Scenario No. 2 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: SIRTF Payload On-Orbit Setup (Manual) Sheet 3 of 5

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
			(bags); egress foot restraints	latches			
12.0	4.5	3.3	Detach foot restraints; tether restraints to spacesuit and translate to sun shield end (starboard side)	Rest; standby; assist CM1; Egress foot restraints		Telescope sun shield/ contamination cover hardware	
15.5	3.5	3.4	Attach foot restraints on starboard side of telescope support cradle; ingress	Attach contamination collector to CM1 life support system sublimator exhaust port			Contamination collector retains water vapor from the sublimator for 18-24 minutes
19.0	3.5	3.5	Attach contamination collector to CM2 life support system	Return to foot restraints; ingress			
23.5	4.5	3.6	Release contamination cover/ front telescope support latches (starboard side); retract cover/support	Retract contamination cover/ support frame to allow sun shield deployment; latch frame in stowed position		Contamination cover hardware	Push cover and support frame forward on track NOTE: Task is time limited
27.0	3.5	3.7	Egress foot restraints, detach and tether to spacesuit; transfer to starboard side of sun shield; Attach foot restraints	Egress foot restraints, detach and tether to spacesuit; transfer to port side of sun shield; Attach foot restraints			NOTE: Tasks remaining are time limited until clear of contamination sensitive area--due to collector capacity
57.0	27.0						

TABLE 2.5.6: SIRTF Task Completion Plans -- Mission Scenario No. 2 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: SIRTF Payload On-Orbit Setup (Manual) Sheet 4 of 5

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
			4.0 Retract sun shield assembly				
2.5	2.5	4.1	Release sun shield deployment lever safety pin (starboard side)	Release sun shield deployment lever safety pin (port side)	Payload Station: track and advise EV crewmen of time remaining on contamination collector	Telescope sun shield hardware	Safety pins (pip pins) for launch/reentry only
7.5	5.0	4.2	Deploy sun shield (coordinate with CM2)	Deploy sun shield (coordinate with CM1)		Sun shield deployment handle	Actuate ratchet handles to deploy sun shield
10.5	3.0	4.3	Lock sun shield in extended position	Lock sun shield			
67.5	10.5						
			5.0 Terminate EVA operations				
3.5	3.5	5.1	Egress foot restraints and translate to starboard side intermediate telescope lock; release safety latch	Egress foot restraints and translate to port side intermediate telescope lock; release safety latch			Completely releases telescope for deployment. Foot restraints remain attached for reentry EVA operations
7.5	4.0	5.2	Translate to tool stowage and stow tools	Translate to airlock and ingress			Transfer contamination collection bag into airlock

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TABLE 2.5.6: SIRTF Task Completion Plans -- Mission Scenario No. 2 (continued)

TASK ANALYSIS: TIMELINES AND PROCEDURES

ACTIVITY TITLE: SIRTF Payload On-Orbit Setup (Manual)

Sheet 5 of 5

TIME (Min.) CUM.	TIME (Min.) TASK	SEQ.	FUNCTION AND CREW TASK: EVA CM1	FUNCTION AND CREW TASK: EVA CM2	FUNCTION AND CREW TASK: OTHER SUPPORT	SYSTEM/PAYLOAD INTERFACES	SPECIAL REQMTS., REMARKS, NOTES
12.0	4.5	5.3	Translate to and ingress airlock	Assist CM1 into airlock		Airlock ingress aids	
79.5 TOTAL EVA TIME	12.0		TOTAL EVA TIME: 1 hr., 20 min.				EVA OPERATIONS COMPLETE

SPACE SHUTTLE EVA

- Adequate lighting is provided by the Orbiter.
- Tools are stowed in a locker mounted on the experiment pallet.
- Two qualified crewmembers are trained and available for performing EVA.

The SIRTF EVA mission scenario no. 2 is classified as a potential planned EVA and is performed in the unaided EVA mode.

SECTION 2.5 BIBLIOGRAPHY

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SECTION 3.0 PAYLOAD EVA TASK SUPPORT REQUIREMENTS

3.1 INTRODUCTION

In the development of representative timelines and procedures based on the hypothetical payload EVA scenarios, EVA mission/task support requirements have been identified in addition to the Orbiter provided accommodations. The additional task support requirements are primarily classified as: (1) ancillary hardware items to aid unscheduled or contingency EVA; and (2) modification/replacement of automated subsystems with manually actuated equipment. The ancillary hardware items will be needed to aid worksite access, for crew and equipment restraints/stabilization, and as additional hand tools to enhance task performance. Modified systems will be required for potential planned EVA scenarios to fully take advantage of extravehicular capabilities. The potential planned EVA scenario missions are designed to replace automated systems with the equipment and interfaces necessary to manually perform the payload operations. The payload EVA task support requirements for each of the scenarios developed by the study are presented in this section.

3.2 EVA BASELINE SUPPORT SYSTEM CAPABILITY

Analysis of the crew tasks required to complete the EVA payload mission scenarios disclosed that the current Shuttle baseline EVA accommodations are sufficient to allow performance of all basic EVA functions and most specific task operations. The basic EVA functions include crew translation, cargo transfer, worksite/payload access, crewmember stabilization/restraint, and payload EV tasks not requiring special tools or crew interfaces. Additional tools and crew/equipment restraints will be required to perform certain EV operations on payloads not presently designed for on-orbit servicing. However, only a minimal quantity of tools in addition to the Shuttle baseline complement is required for mission (EVA scenario) completion.

The Shuttle Orbiter will provide an EVA mobility aid system (e.g., handrails,

handholds, and tethers) to ingress/egress the airlock and access the forward bulkhead, payload bay and aft bulkhead. Many payloads can be accessed using only the Orbiter accommodations; however, any additional mobility aids required to access specific payload areas must be provided by the payload. Manned Maneuvering Units (MMU's) will be available to the payload community to access free-flying satellites and are payload weight chargeable if used primarily to support payload operations.

The Orbiter will provide EV crew restraint systems (foot restraints, tethers) on each Shuttle flight. The quantity was undefined at report preparation. For purposes of this study, it was assumed that foot restraints would be provided at no cost to the payload for the retrieval of tools, support equipment or spare hardware from a payload bay stowage facility. Additional units are provided by the user as weight chargeable items.

The Shuttle also provides all systems directly supporting the crewmembers in the extravehicular environment including spacesuits, life support systems, and consumables. The baseline EVA accommodations include all provisions to support 2, two-man EVA's of 6 hours duration each on every Shuttle flight. Provisions for additional EVA capability may be incorporated into the Shuttle as mission kits weight chargeable to the payload.

In comparing the EVA task scenario requirements with the supporting capabilities of the Shuttle baseline EVA system, the following fundamental elements were considered in establishing satisfactory EV operational conditions/interfaces:

- Required expansion of the Shuttle Orbiter baseline EVA system
- Required performance improvements of the Orbiter baseline EVA system
- Task performance requirements that were beyond the capabilities of the baseline EVA system
- Task design alternatives that will bring task performance within the capability of the EVA system

- Additional EVA support equipment required from the Shuttle baseline inventory but payload chargeable
- New items to be provided by the payload to effect task completion.

3.3 EVA TASK SUPPORT REQUIREMENTS

The payload EVA task support requirements derived from the representative mission scenarios are summarized in Table 3.3.1. The requirements summary lists only the additional EVA equipment and baseline system performance improvements considered necessary to ensure efficient task performance. Task/hardware design alternatives required in the modification of automated experiments to bring task performance within the capability of the EVA system may be found in Tables 3.3.2 through 3.3.10. Table 3.3.1 is provided for convenience to depict general requirements across the specific payloads reviewed.

Each of the nine EVA mission scenarios developed will require support equipment in addition to Orbiter provided accommodations. However, the majority of planned, unscheduled and contingency operations/tasks can be accomplished with a minimum of new equipment. Additional equipment identical/similar to that provided in the Orbiter EVA accommodations inventory will suffice for completing the majority of EVA payload tasks in the categories noted above.

The potential planned payload tasks (i.e., replacing automated systems) will require hardware design alternatives to configure the payload for on-orbit EVA servicing. The scenarios depicting potential planned EVA operations, as the hardware is presently conceived, require certain operations that may be beyond the capabilities (or marginal) of the crewman and baseline EVA system. The "marginal" EVA operations capabilities result primarily from: (1) limited EV crewman access, (2) inherent interface design (i.e., limited man-machine interface) of automated hardware, (3) force-torque requirements, and (4) massive equipment handling.

TABLE 3.3.1: Payload EVA Task Support Requirements Summary

EVA SYSTEM BASELINE EXPANSION AND SYSTEM PERFORMANCE IMPROVEMENT REQUIREMENTS			
SUPPORT REQUIREMENT	RATIONALE	QUANTITY REQUIRED	REMARKS
Portable EVA Handholds	Provide crew stabilization at various unscheduled worksites and ingress aid for EVA portable foot restraints	4 per flight	Portable handholds with attachment capability to flat surfaces and structural shapes
Magnetic Small Parts Retainer	Provide temporary stowage of ferrous and nonferrous parts; assist capture of ferrous parts	1 per flight	Control loose parts removed during EVA operations (bolts, nuts, fasteners, spacers, etc.)
Small Items Carryall Container	Assist in EVA support equipment and tool transfer; temporary on-orbit stowage at EV worksite	2 per flight	Soft "bag" type container
Portable Lights	Used to illuminate EVA worksite	2 per flight	To be used by payload or Orbiter as required
Utility Outlets	Power supply for portable lights, power tools, etc.	6 per vehicle	Permanent units on all Orbiter vehicles

SPACE SHUTTLE EVA

The payload EVA task support requirements for each of the mission scenarios developed are provided in the following tables:

ADVANCED TECHNOLOGY LABORATORY

1. Interferometer Boom Release and Development -- Table 3.3.2 (unscheduled EVA)
2. Deploy ATL (Mission 11) Pallet Mounted Experiment Subsystems -- Table 3.3.3 (potential planned EVA)

LOW COST MODULAR SPACECRAFT

1. Deploy Payload -- Table 3.3.4 (unscheduled EVA)
2. Recover Damaged LCMS -- Table 3.3.5 (contingency EVA)
3. Refurbish LCMS -- Table 3.3.6 (potential planned EVA)

LARGE SPACE TELESCOPE

1. LST Scheduled Maintenance -- Table 3.3.7 (planned EVA)
2. Retract Failed Solar Array Panel -- Table 3.3.8 (unscheduled EVA)

SHUTTLE INFRARED TELESCOPE FACILITY

1. Configure SIRTF Hardware for Reentry -- Table 3.3.9 (contingency EVA)
2. Payload On-orbit Setup (Manual) -- Table 3.3.10 (potential planned EVA).

TABLE 3.3.2: Payload EVA Task Support Requirements -- ATL Mission Scenario No. 1

MISSION SCENARIO: Interferometer Boom Release and Deployment

EVA CLASSIFICATION: Unscheduled EVA
Unaided EVA Mode

SUPPORT REQUIREMENTS	TASK OR OPERATION	QUANTITY REQUIRED (per flt)	REQUIREMENTS RATIONALE: EVA SYSTEM EXPANSION	SYSTEM PERFORMANCE IMPROVEMENT	BEYOND CAPABILITY AS NOW DESIGNED	HARDWARE ALTERNATE DESIGN	ADDITIONAL BASELINE EVA INVENTORY HDW.	NEW ITEMS PROVIDED BY PAYLOAD	REMARKS
EVA Handrail	Access pallet mounted equipment	12 m. (40 ft.)					●		Continuation of Orbiter baseline
Portable Handholds	Ingress foot restraint and stability at worksite	3 each	●						Stabilization at worksite
Portable EVA Work-station	All EVA tasks requir-ing force application	1 set					●		Crew restraint at worksite
Magnetic Parts Retainer	Retain bolts, fasten-ers, etc.	1 each	●						Retain bolts and hardware items
Small Item Carry-All Container	Temp. stow loose equipment	2 each	●						
Pry Bar	Service boom canister	1 each						●	24 in. pry bar

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TABLE 3.3.2: Payload EVA Task Support Requirements -- ATL Mission Scenario No. 1 (Continued)

MISSION SCENARIO: Interferometer Boom Release and Deployment

EVA CLASSIFICATION: Unscheduled EVA
Unaided EVA Mode

SUPPORT REQUIREMENTS	TASK OR OPERATION	QUANTITY REQUIRED (per flt)	EVA SYSTEM EXPANSION	SYSTEM PERFORMANCE IMPROVEMENT	BEYOND CAPABILITY AS NOW DESIGNED	HARDWARE DESIGN ALTERNATE	ADDITIONAL BASELINE EVA INVENTORY HDW.	NEW ITEMS PROVIDED BY PAYLOAD	REMARKS
EVA Tethers	Equip. and crew restraint	3 each					●		
Wrench Set	Remove launch lock and strut	1 set						●	5 piece combination open/box end set from 7/16" through 3/4"

REQUIREMENTS RATIONALE

TABLE 3.3.3: Payload EVA Task Support Requirements -- ATL Mission Scenario No. 2

MISSION SCENARIO: Deploy ATL (Mission 11) Pallet Mounted Experiment Subsystems

EVA CLASSIFICATION: Potential Planned EVA Unaided EVA Mode

SUPPORT REQUIREMENTS	TASK OR OPERATION	QUANTITY REQUIRED (per flt)	REQUIREMENTS RATIONALE: EVA SYSTEM EXPANSION	SYSTEM PERFORMANCE IMPROVEMENT	BEYOND CAPABILITY AS NOW DESIGNED	HARDWARE DESIGN ALTERNATE	ADDITIONAL BASELINE EVA INVENTORY HDW.	NEW ITEMS PROVIDED BY PAYLOAD	REMARKS
EVA Handrail	Access pallet mounted equip.	20 m. (65 ft.)					●		Continuation of Orbiter baseline
Portable EVA Work-station	All EVA tasks requiring force application	2 sets					●		Crew restraint at worksite
EVA Tethers	Equip. and crew restraint	2 each					●		
Boom Deployment Tool	Experiment subsystem deployment	2 each						●	Special ratchet hand tool to deploy ATL elements
Workstation Attachment Interface	Deploy EVA workstation	6			●	●		●	Passive interface for workstation
Manual Launch Locks	Release Interferometer Boom Canister	4				●		●	Replaces automated units

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TABLE 3.3.3: Payload EVA Task Support Requirements -- ATL Mission Scenario No. 2 (Continued)

MISSION SCENARIO: Deploy ATL (Mission 11) Pallet Mounted Experiment Subsystems

EVA CLASSIFICATION: Potential Planned EVA Unaided EVA Mode

SUPPORT REQUIREMENTS	TASK OR OPERATION	QUANTITY REQUIRED (per flt)	REQUIREMENTS RATIONALE: EVA SYSTEM EXPANSION	SYSTEM PERFORMANCE IMPROVEMENT	BEYOND CAPABILITY AS NOW DESIGNED	HARDWARE DESIGN ALTERNATE	ADDITIONAL BASELINE EVA INVENTORY HDW.	NEW ITEMS PROVIDED BY PAYLOAD	REMARKS
Boom Canister Deployment Drive Mechanism	Deploy Interferometer Boom Canisters	1				●		●	Gear drive unit with hand tool interface and support hdw.
Interferometer Boom Extension Drive Mechanism	Deploy Interferometer Booms	1			●	●		●	Gear drive unit with hand tool interface and support hdw.
SLR Antenna Tilt Launch Locks	Release antenna tilt mechanism	2				●		●	Manually actuated launch locks
Antenna Deploy Launch Locks	Release antenna for deployment	2				●		●	Manually actuated launch locks
Antenna Deployment Drive Mechanism	Deploy antenna	1				●		●	Gear drive unit with hand tool interface and support hdw.
Environmental Effects Experiment (EEE) Boom Deployment Tool Interface	Deploy EEE sample container	1			●	●		●	Modify "STEM" unit to accept hand tool and add retention pin

TABLE 3.3.3: Payload EVA Task Support Requirements -- ATL Mission Scenario No. 2 (Continued)

MISSION SCENARIO: Deploy ATL (Mission 11) Pallet Mounted Experiment Subsystems

EVA CLASSIFICATION: Potential Planned EVA
Unaided EVA Mode

SUPPORT REQUIREMENTS	TASK OR OPERATION	QUANTITY REQUIRED (per flt)	REQUIREMENTS RATIONALE: EVA SYSTEM EXPANSION	SYSTEM PERFORMANCE IMPROVEMENT	BEYOND CAPABILITY AS NOW DESIGNED	HARDWARE DESIGN ALTERNATE	ADDITIONAL BASELINE EVA INVENTORY HDW.	NEW ITEMS PROVIDED BY PAYLOAD	REMARKS
EEE Launch Lock	Release boom	1				◐		○	Manually actuated launch lock
UV Meter Cover Launch Locks	Release contamination cover	2				○		◐	Manually actuated launch locks
UV Meter Manual Vent Valve	Vent contamination container	2				●		●	Manual vent
Autonomous Nav. Cover Launch Locks	Release telescope contamination cover	2				◐		●	Manually actuated launch locks
Auto. Nav. Manual Vent Valve	Vent contaimination container	2				◐		◐	Manual vent
Lidar Unit Cover Launch Locks	Release contamination cover	2				◐		●	Manually actuated launch locks
Lidar Unit Manual Vent Valve	Vent contamination container	2				◐		◐	Manual vent

TABLE 3.3.4: Payload EVA Task Support Requirements -- LCMS Mission Scenario No. 1

MISSION SCENARIO: Deploy Payload

EVA CLASSIFICATION: Unscheduled EVA
EVA with MMU Mode

SUPPORT REQUIREMENTS	TASK OR OPERATION	QUANTITY REQUIRED (per flt)	REQUIREMENTS RATIONALE: EVA SYSTEM EXPANSION	SYSTEM PERFORMANCE IMPROVEMENT	BEYOND CAPABILITY AS NOW DESIGNED	HARDWARE DESIGN ALTERNATE	ADDITIONAL BASELINE EVA INVENTORY ITEM	NEW ITEMS PROVIDED BY PAYLOAD	REMARKS
Portable Lights	Portable light placement	2 ea.	●						Illuminate worksite
Portable Light Brackets and Fittings	Portable light attachment	2 ea.						●	Attach to retention cradle structure
Utility Outlets	Power for lights	6 ea.	●	●	●				Three each side of payload bay
Loop Pin Removal Tool	Remove retention cradle latches	1 ea.						●	Pin removal is first task in latch removal operation
Pry Bar	Remove retention cradle latches	1 ea.						●	24 in. pry bar
Portable EVA Workstation	All tasks requiring force application	2 sets					●		Stabilization at worksite
Manned Maneuvering Unit	All EVA operations outside P/L bay	2 ea.					●		Translation
EVA Tethers	Equipment/crew restraint	3 ea.					●		

TABLE 3.3.5: Payload EVA Task Support Requirements -- LCMS Mission Scenario No. 2

MISSION SCENARIO: Recover Damaged LCMS

EVA CLASSIFICATION: Contingency EVA
Unaided EVA Mode

SUPPORT REQUIREMENTS	TASK OR OPERATION	QUANTITY REQUIRED (per flt)	REQUIREMENTS RATIONALE: EVA SYSTEM EXPANSION	SYSTEM PERFORMANCE IMPROVEMENT	BEYOND CAPABILITY AS NOW DESIGNED	HARDWARE DESIGN ALTERNATE	ADDITIONAL BASELINE EVA INVENTORY HDW.	NEW ITEMS PROVIDED BY PAYLOAD	REMARKS
Come-along (winch-type device)	Pull damaged solar array from RMS	1 ea.				●			Candidate item for P/L bay door repair kit.
Bolt Cutters	Cut bolts, cables and structure to permit array jettisoning	1 ea.					●		For contingency operations
EVA Tethers	Equipment/array handling and restraint	3 ea.				●			

TABLE 3.3.6: Payload EVA Task Support Requirements -- LCMS Mission Scenario No. 3

MISSION SCENARIO: Refurbish LCMS

EVA CLASSIFICATION: Potential Planned EVA
EVA with RMS Mode

SUPPORT REQUIREMENTS	TASK OR OPERATION	QUANTITY REQUIRED (per flt)	REQUIREMENTS RATIONALE: EVA SYSTEM EXPANSION	SYSTEM PERFORMANCE IMPROVEMENT	BEYOND CAPABILITY AS NOW DESIGNED	HARDWARE DESIGN ALTERNATE	ADDITIONAL BASELINE EVA INVENTORY ITEM	NEW ITEMS PROVIDED BY PAYLOAD	REMARKS
Modified LCMS Positioning Platform	Dock and position LCMS for maintenance operations	1 ea.		●		●		●	All automated functions deleted
Power/Checkout Cable	Supply power during maintenance checkout operations	1 ea.				●		●	Manual connection performed by EVA crewman
Special EVA Workstation	Provides access for module replacement and positioning platform orientation	1 ea.				●		●	To be stowed in the proximity of the LCMS work area and deployed after LCMS docking
Equipment Tethers	Module stabilization during transfer and pre-installation operations	4 ea.					●		
Module storage pallet	Store replacement modules for on-orbit servicing---return spent modules to earth	1 ea.		●		●		●	Includes foot restraints, handrails, low-level utility platform
Motor Unit	Actuate module latches, rotate pos. platform	1 ea.				●		●	Hand-held unit

TABLE 3.3.7: Payload EVA Task Support Requirements -- LST Mission Scenario No. 1

MISSION SCENARIO: LST Scheduled Maintenance

EVA CLASSIFICATION: Planned EVA, Unaided EVA Mode

SUPPORT REQUIREMENTS	TASK OR OPERATION	QUANTITY REQUIRED (per flt)	REQUIREMENTS RATIONALE: EVA SYSTEM EXPANSION	SYSTEM PERFORMANCE IMPROVEMENT	BEYOND CAPABILITY AS NOW DESIGNED	HARDWARE ALTERNATE DESIGN	ADDITIONAL BASELINE EVA INVENTORY ITEM	NEW ITEMS PROVIDED BY PAYLOAD	REMARKS
LST Stabilizing Strut	Stabilize payload during maintenance	1 ea.				●		●	Allows RMS disengagement
EVA Handrail	Access stowage rack, restrain crewmen and portable lights	4.6 m. (15 ft.)					●		Part of equipment stowage rack
Portable Light Assembly	Illuminate payload exterior worksites	2 ea.	●					●	TBD watts each
Utility Electrical Outlets	Power for portable light assembly	6 ea.	●	●	●				Three each side of Orbiter payload bay
Portable EVA Workstation	All EVA tasks requiring force application, tool kit and auxiliary lighting	1 set					●		Crew restraint, hand tools and illumination at worksite
EVA Tethers	Equipment and crew restraint	8 ea.					●		6 equipment, 2 crew
Tool Kit/Hand Tools	Spare equipment and SSE removal/install.	1 set			●			●	For use at stowage racks

TABLE 3.3.7: Payload EVA Task Support Requirements -- LST Mission Scenario No. 1 (continued)

MISSION SCENARIO: LST Scheduled Maintenance

EVA CLASSIFICATION: Planned EVA
Unaided EVA Mode

SUPPORT REQUIREMENTS	TASK OR OPERATION	QUANTITY REQUIRED (per flt)	REQUIREMENTS RATIONALE: EVA SYSTEM EXPANSION	SYSTEM PERFORMANCE IMPROVEMENT	BEYOND CAPABILITY AS NOW DESIGNED	HARDWARE ALTERNATE DESIGN	ADDITIONAL BASELINE EVA INVENTORY HDW.	NEW ITEMS PROVIDED BY PAYLOAD	REMARKS
EVA Handrail	Access payload exterior worksites	23 m. (75 ft.)					●		Longitudinal and circumferential
Equipment Transfer Rod	Transport equipment between stowage and worksite	1 ea.		●				●	Adjustable length
Workstation Attachment Interface	Deploy EVA workstation	4 ea.				●		●	Passive interface for workstation
Fixed Interior Lights	Illuminate payload interior worksite	6 ea.						●	TBD watts each
Fixed Foot Restraints	Crewman restraint in payload aft compartment	2 sets					●		2 pair per SI module mounted on aft bulkhead
Fixed Handholds	Ingress foot restraints and stabilize at worksite	2 ea.					●	●	Stabilization at worksite
Monorail Transfer	Transport SI modules between stowage and installation worksite	1 ea.		●		●		●	Self-aligning interconnecting track sections with two transfer carriages

TABLE 3.3.8: Payload EVA Task Support Requirements -- LST Mission Scenario No. 2

MISSION SCENARIO: Retract Failed Solar Array Panel

EVA CLASSIFICATION: Unscheduled EVA
EVA With MMU Mode

SUPPORT REQUIREMENTS	TASK OR OPERATION	QUANTITY REQUIRED (per flt)	REQUIREMENTS RATIONALE: EVA SYSTEM EXPANSION	SYSTEM PERFORMANCE IMPROVEMENT	BEYOND CAPABILITY AS NOW DESIGNED	HARDWARE DESIGN ALTERNATE	ADDITIONAL BASELINE EVA INVENTORY HDW.	NEW ITEMS PROVIDED BY PAYLOAD	REMARKS
Crewman Portable Light (Battery Powered)	Illuminate worksite	2 ea.						●	Stowed in Orbiter cabin
EVA Handrail	Access payload exterior worksite	10 m. (33 ft.)					●		Longitudinal and circumferential
EVA Tethers	Equipment/crew restraint	5 ea.					●		3 equipment, 2 crew
Portable EVA Workstation	EVA tasks requiring force application, tool kit and auxiliary lighting	1 set					●		Crewman restraint, hand tools and illumination at worksite
Small Item Carry-all Container	Temporary stowage and transport of loose hardware	1 ea.	●						
Magnetic Parts Retainer	Retain fasteners, small parts, etc.	1 ea.	●						Retain small hardware items during handling

TABLE 3.3.9: Payload EVA Task Support Requirements -- SIRTF Mission Scenario No. 1

MISSION SCENARIO: Configure SIRTF Hardware for Reentry

EVA CLASSIFICATION: Contingency EVA
Unaided EVA Mode

SUPPORT REQUIREMENTS	TASK OR OPERATION	QUANTITY REQUIRED (per flt)	REQUIREMENTS RATIONALE: EVA SYSTEM EXPANSION	SYSTEM PERFORMANCE IMPROVEMENT	BEYOND CAPABILITY AS NON DESIGNED	HARDWARE DESIGN ALTERNATE	ADDITIONAL BASELINE EVA INVENTORY HDW.	NEW ITEMS PROVIDED BY PAYLOAD	REMARKS
NOTE: ALL EQUIPMENT REQUIRED FOR THE SIRTF MISSION SCENARIO IS ASSUMED TO BE AVAILABLE IN ORBITER TOOL STOWAGE.									
Wrench Set	Secure telescope, front launch locks	1 set					●		5-pc. combination open/box end set from 7/16" through 3/4"
EVA Equipment Tethers	Equip./crew restraint	6 ea.					●		
Foot Restraints	All tasks requiring force application	1 set					●		Crew restraint at worksite
Ratchet (3/8" drive) and Extension	Gimbal release	1 set					●		Standard Orbiter tools
Pry Bar	Engage intermediate launch lock	1 ea.					●		16 in. pry bar

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TABLE 3.3.10: Payload EVA Task Support Requirements -- SIRTF Mission Scenario No. 2

MISSION SCENARIO: SIRTF Payload On-Orbit Setup (Manual)

EVA CLASSIFICATION: Potential Planned EVA
Unaided EVA Mode

REQUIREMENTS RATIONALE

NOTE: THIS SIRTF EVA MISSION IS ASSUMED TO BE DESIGNED TO ALLOW PAYLOAD SETUP USING ONLY STANDARD TOOLS AND EQUIPMENT SELECTED FROM THE ORBITER MASTER TOOL LIST.

SUPPORT REQUIREMENTS	TASK OR OPERATION	QUANTITY REQUIRED (per flt)	EVA SYSTEM EXPANSION	SYSTEM PERFORMANCE IMPROVEMENT	BEYOND CAPABILITY AS NOW DESIGNED	HARDWARE DESIGN ALTERNATE	ADDITIONAL BASELINE EVA INVENTORY ITM.	NEW ITEMS PROVIDED BY PAYLOAD	REMARKS
Manual Thermal Isolator Actuation Mechanisms	Retract thermal isolators	TBD				●		●	Replaces automated units and support subsystems
Manual IPS Caging Mechanism(s)	Uncage gyros	TBD				●		●	
Manual Mirror Caging Mechanisms	Uncage mirror	2 ea.				●		●	
Manual IPS Launch Locks (Intermediate)	Release intermediate Instrument Pointing System launch locks	2 ea.				●		●	
EMU Contamination Collectors	Collects H_2O vapor from EV life support system sublimator	2 ea.				●		●	Requires feasibility study
Manual Contamination Cover Release Mechanism	Release contamination cover	TBD				●		●	Replaces automated units and support subsystems

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TABLE 3.3.10: Payload EVA Task Support Requirements -- SIRTF Mission Scenario No. 2 (continued)

MISSION SCENARIO: SIRTF Payload On-Orbit Setup (Manual)

EVA CLASSIFICATION: Potential Planned EVA; Unaided EVA Mode

SUPPORT REQUIREMENTS	TASK OR OPERATION	QUANTITY REQUIRED (per flt)	REQUIREMENTS RATIONALE: EVA SYSTEM EXPANSION	SYSTEM PERFORMANCE IMPROVEMENT	BEYOND CAPABILITY AS NOW DESIGNED	HARDWARE DESIGN ALTERNATE	ADDITIONAL BASELINE EVA INVENTORY HDW.	NEW ITEMS PROVIDED BY PAYLOAD	REMARKS
Manual Latches on Telescope Front Support	Release telescope	2 ea.				●		●	Replaces automated units and support subsystems
Manual Sun Shield Deployment Mechanism	Deploy telescope sun shield	1 ea.				●		●	

SECTION 4.0 EV PREPARATION AND POST ACTIVITIES

4.1 INTRODUCTION

Prior to egressing the spacecraft cabin to perform extravehicular activities, two operations are mandatory for crew survival in the reduced-pressure, "weightless" environment: (1) donning a protective spacesuit assembly and life support system, and (2) prebreathing pure oxygen for entering the reduced pressure environment. The time required for the crewmen to prepare the Orbiter subsystems and EVA support equipment, and the prebreathing requirement, are of concern to both the Orbiter and payloads. In considering EVA for payload operations (from an economic standpoint), the payload community is primarily concerned with a possible reduction in on-orbit time available to conduct the scientific experiments. Both the payloads and Orbiter are concerned with the capability for a rapid EVA response in the event of an on-orbit contingency situation.

In considering EVA for planned payload operations, it should initially be noted that the EVA preparation time does not constitute a block of time specifically set aside after on-orbit payload operational attitude is attained. EVA preparation functions can be performed in parallel with Orbiter and other payload preparation requirements. The following subsections provide a nominal time for EVA preparation and post-EVA activities based on EVA systems information available in early 1976, including preliminary times for rapid EVA response to planned payload requirements.

4.2 EVA PREBREATHE

The prevention of dysbarism (decompression sickness/bends) from occurring in spaceflight is of major significance in Shuttle EVA missions. When the EVA crewmembers are to be subjected to a 206 mmHg (4.0 psia) pure oxygen (O_2) pressure environment from the 760 mmHg (14.7 psia) mixed gas Shuttle cabin atmosphere, 3.5 hours of oxygen prebreathing are required. The prebreathing can be interrupted prior to the final one hour if equal interruption time is

added to the total prebreathe time. However, to iterate, the final one hour of prebreathing prior to entering the 206 mmHg (4.0 psia) pure O_2 spacesuit environment cannot be interrupted.

To accomplish prebreathing (denitrogenization) the EVA crewman will use a portable oxygen system (POS) with a quasi-"walk-around" capability. The portable oxygen system will use an umbilical system connected to the Orbiter Environmental Control System (ECS) as the primary operational mode. The POS will also contain an internal oxygen supply to provide a ten-minute independent "walk-around" capability. The walk-around capability, however, will normally be reserved for contingency situations. POS oxygen supply connections (i.e., quick disconnects) are provided at various locations in the Shuttle Orbiter cabin.

The final 1.5 hours (approximately) of the prebreathe phase only will be allocated to preparing the Orbiter subsystems and EVA support equipment (e.g., spacesuit, life support systems, airlock) for EV operations. However, the time prior to EVA prep will be available for performing payload functions. Both the prebreathe and EVA preparation functions, including spacesuit donning, can be performed solely by the EVA crewmen. No assistance from other crewmen is required with the exception of communications system operation verification.

4.3 EVA PREPARATION OPERATIONS

The time required for the EV crew to prepare the spacecraft and EVA support equipment for external activities has been estimated although the EV hardware and Orbiter interfaces have not been finalized (early 1976). Table 4.3.1 provides a summarized set of pre- and post-EVA operations and timelines for a nominal EVA mission including prebreathing. The table is not intended to provide a detailed explanation of each EVA required operation. Instead, a block of time is allocated to specific areas and/or generic operations.

After the POS is unstowed and donned for prebreathing, the EV crewmembers

TABLE 4.3.1: Nominal EVA Preparation and Post-EVA Time Requirements

EVA FUNCTION	PRE-BREATHE	CREW TIME (min.)	REMARKS/EXPLANATION
START EVA PREBREATHE			
START PREBREATHE		5	Prebreathing equipment (rebreather, O_2 umbilical, and mask) is unstowed, connected and operationally checked.
CONTINUE PREBREATHE		115	Crewman starts prebreathing and continues for up to 3.5 hours. During the 2-hour period prior to EVA preparation, the crewman may perform non-EVA related activities.
START EVA PREPARATION			
CABIN PREPARATION		10	Airlock and lower deck area are configured for life support equipment and suit donning. Donning aids, such as restraint devices and temporary stowage compartments, are unstowed and positioned, as required.
EQUIPMENT PREPARATION		15	Equipment required for EVA (i.e., suits, life support equipment, tethers, etc.) are unstowed and positioned for donning. Preliminary checkout of the equipment will be performed, as required.

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TABLE 4.3.1: Nominal EVA Preparation and Post-EVA Time Requirements (continued)

EVA FUNCTION	PRE-BREATHE	CREW TIME (min.)	REMARKS/EXPLANATION
SPACESUIT AND LIFE SUPPORT SYSTEM DONNING		30	Inflight suits are doffed and stowed. EVA and ancillary equipment (i.e., crewman's waste management system and liquid cooling garment) are donned. Spacesuit and life support systems are donned. Crewman connects to the airlock water cooling umbilicals.
HELMET AND GLOVE DONNING		15	O_2 purge of EMU is performed. Crewman doffs rebreather and dons comm carrier, helmet and gloves.
COMMUNICATION CHECK		10	Comm check between the PLSS and the Orbiter comm system is made. PLSS telemetry is checked. Backup PLSS comm modes are also checked.
INTEGRITY CHECK		5	An integrity check of the EMU's is performed prior to completion of airlock depress. This is a gross check of the EMU to verify that all connections are made and that leakage is acceptable.
AIRLOCK DEPRESS		6	Airlock depress will be performed by the EVA crewman. Depress will be interrupted at least once to verify EMU and airlock integrity.

TABLE 4.3.1: Nominal EVA Preparation and Post-EVA Time Requirements (continued)

EVA FUNCTION	PRE-BREATHE	CREW TIME (min.)	REMARKS/EXPLANATION
HATCH OPENING		4	After opening and securing outer airlock hatch, the crew will initiate start-up of PLSS cooling. After cooling has been established, crew will begin the EVA.
PREPARATION TOTAL	3.5 HOURS	215	EVA prebreathing and preparation
EVA TASKS PERFORMED			
EVA MISSION OPERATIONS TIME ESTIMATE			Up to 6 hours of EVA
POST-EVA FUNCTIONS			

EVA FUNCTION	CREW TIME (min.)	REMARKS/EXPLANATION
HATCH CLOSING	5	After completion of EVA, crewman ingresses the air-lock; PLSS cooling is shut down and outer airlock hatch closed.

TABLE 4.3.1: Nominal EVA Preparation and Post-EVA Time Requirements (continued)

EVA FUNCTION	CREW TIME (min.)	REMARKS/EXPLANATION
AIRLOCK REPRESS	5	Crewman represses airlock and verifies airlock integrity.
HELMET AND GLOVE DOFFING	10	After suit pressure is equalized with ambient, crewman doffs and stows helmet and gloves and connects to the Orbiter water cooling system. The PLSS is deactivated.
SUIT DOFFING	20	PLSS and suit are doffed and secured. Crewman also doffs ancillary suit equipment and dons flight suit. Suits and ancillary equipment are stowed unless suit drying is required.
PLSS RECHARGE	20	PLSS consumables are replaced. PLSS is prepared and secured for next EVA. Loose equipment, such as tethers and cameras, is stowed.
SUIT DRYING	20	Suit drying is initiated, if required. If not, suits and ancillary equipment are stowed, and the lower deck/airlock are returned to pre-EVA configuration.
POST-EVA TOTAL	80	

NOTE: Timeline and sequences outlined are typical of those required for Shuttle EVA preparation and post-EVA activities. They are subject to change as equipment required to support EVA is better defined and procedures are optimized.

will have approximately 2.0 hours prior to EVA equipment preparation and donning for performing payload associated tasks. The crewmen can perform tasks on the Orbiter flight deck and mid-deck within reach of the POS umbilical. Tasks in these areas can be performed on a continuous basis throughout the 2.0 hour period. The EV crewmen may (pending further study relative to baseline POS utilization) use the POS internal O_2 supply (tank) for tasks remote from the ECS oxygen supply. The internal tanks can be recharged on-orbit. Each remote task cannot exceed an estimated 10 minutes before the crewman is required to return to the Orbiter ECS oxygen supply. Since the POS is a chest-mounted unit with a facemask, the crewman is not significantly encumbered during task performance.

The remaining 1.5 hours of the required prebreathe phase will be dedicated primarily to configuring the Orbiter subsystems and EVA support systems for external operations and donning/checkout of EVA equipment. However, payload systems or operations requiring periodic monitoring/actuation from internal control panels can be performed by the EV crewmen prior to spacesuit ingress. The EV crewman should remain on the POS prebreathe system during the total 3.5 hours, independent of task performance, to avoid "makeup" prebreathing. Tradeoff studies should be performed for each planned EVA mission for optimum support of payload requirements during the prebreathe and EVA preparation phase. Various procedural options will be available.

4.4 POST-EVA OPERATIONS

Following airlock ingress and repressurization, the EV crewmen initiate spacesuit and life support system doffing and configure the EVA equipment for stowage or subsequent operation (Ref. Table 4.3.1). The post-EVA operations require approximately 80 minutes from airlock hatch closing to completion under nominal EVA termination. However, when two-man EVA's are conducted, one EVA crewman can doff the EVA gear and be available for payload internal support within approximately 30 minutes if required. The second EV crewman would continue the equipment doffing, servicing and stowage until complete. The EVA support equipment (i.e., spacesuit and

life support systems) must be readily prepared for subsequent EVA's in the event of a contingency requirement. Ancillary, loose support equipment (e.g., cameras, tethers) may be temporarily stowed and secured later if payload support requirements are immediate.

Several procedural options for post-EV operations will be available. Procedures specifically applicable to the individual payloads are developed and crewmembers cross-trained in EVA and payload operations.

4.5 EVA RAPID RESPONSE CAPABILITY

The capability to respond to Orbiter and payload requirements as quickly as possible from launch can be critical to personnel rescue from a disabled space vehicle. A rapid EVA response capability after orbit is attained may enhance payload operations and scientific/defense data acquisition. The capability to perform a second EVA with rapid on-orbit response time could also be advantageous to the payload community.

Although the Orbiter and EVA supporting subsystems were not sufficiently finalized at report preparation to formulate detailed rapid EVA response procedures and timelines, such procedures will be developed by NASA for EVA rescue operations. For payloads requiring immediate crewman access after reaching orbit, portions of the rapid EVA rescue procedures could be adapted to payload operations. The following subsections present possible options to effect prompt EVA response to payload requirements only. Many of the possible options will require further study by NASA when the Orbiter subsystems and EVA support equipment designs are complete and final performance capability data are available. It should be noted that the rapid EVA response techniques/operations are conceptual only and are not baseline Shuttle or payload procedures--the intent is to illustrate that rapid EVA response to payload requirements can be incorporated into the Shuttle Program.

4.5.1 Rapid Response to Planned EVA Payload Operations

Payloads utilizing the Shuttle EVA capability may require manned access to the payload immediately upon reaching orbit to fully capitalize on scientific data acquisition. Since 3.0 to 3.5 hours of crewmember prebreathing are mandatory for denitrogenization, prebreathing prior to reaching orbit may be advantageous. The Space Shuttle requires only approximately 40 minutes to reach a nominal 270 km. (150 Nm.) orbit. Depending on electrical power and initial checkout requirements, the payloads may immediately be operational or require in excess of 12 hours preparation after reaching orbit. A rapid EVA response to the immediately-operational payloads may require prebreathing prior to launch.

Prebreathing options that may be considered by the payload community to satisfy rapid EVA response requirements include:

- Mission Specialist(s) initiate prebreathe prior to vehicle launch and continue uninterrupted until EVA
- Pilot and Mission Specialist(s) initiate prebreathing prior to reaching final orbit (i.e., prior to OMS burn).

Provisions for the above are not presently Shuttle baselined and will require study. Additional support hardware required to effect the prebreathing capability concepts may be payload chargeable in mission kit form.

Assuming the crew prebreathing requirements can be satisfied, further time reduction may be realized in the preparation, checkout and donning of EVA support hardware. In nominal EVA operations, approximately 90 minutes are allowed for EVA preparation. The following may be Shuttle baseline options or operationally feasible if increased crew safety risks are acceptable to the payload:

- Launch the EVA hardware (EMU) with all systems fully charged
- Perform all EVA systems operational checkouts prior to launch--

repeat only crew safety critical checkouts on orbit

- Use additional crewmembers (other than EVA) to assist EVA preparation.

Depending on the number of crewmembers aboard and Orbiter operational requirements, it appears feasible to provide an EVA capability within 30-40 minutes after vehicle attitude stabilization on orbit.

4.5.2 Rapid Response to Subsequent EVA

The nominal time required to prepare the extravehicular equipment for a second EVA can be up to 16 hours. The 16-hour turn-around time is based on the requirement to recharge the primary life support system (PLSS) batteries. If spare batteries are aboard, the time is based on the 3.5 hour mandatory prebreathe requirement. If the EV crewman, after returning from an EVA mission, breathes the Orbiter cabin mixed gas atmosphere for less than 2.5 hours, only the time the cabin atmosphere was breathed plus one hour will be required for prebreathe: for example, if the crewman returns from an EVA mission, breathes the cabin atmosphere for 45 minutes, the required prebreathe time is 1 hour 45 minutes since the final one hour of prebreathe cannot be interrupted (Shuttle baseline).

If back-to-back subsequent EVA's are planned, the EVA equipment changeout operations can be accomplished in as little as 30 minutes depending on the quantity of spare EVA equipment available. If spare PLSS and upper spacesuit torso assemblies are aboard, the time required is based on airlock repressurization, upper torso doffing/donning and airlock depressurization. To avoid prebreathing, the EV crewman would utilize the portable oxygen system (POS) during upper torso assembly exchange. The operation should require approximately 30 minutes.

The primary life support system is designed to be recharged for on-orbit reuse by one man within one hour. If only spare batteries are aboard the Orbiter, the subsequent EVA preparation time would be one hour plus airlock

pressurization operations. Approximately 1 hour 20 minutes total turn-around time would be required for the "PLSS recharge" subsequent EVA mode.

4.6 AIRLOCK EQUIPMENT TRANSFER CAPACITY

A capability of importance to the payload community is the transfer of experiment and payload maintenance equipment through the Shuttle airlock. The airlock, independent of the cabin interior or payload bay location, will provide the capability to transport packages with maximum dimensions of 46 cm. x 46 cm. x 127 cm. (18 in. x 18 in. x 50 in.) from the cabin into the payload bay. The number of maximum dimension packages with both one and two spacesuited crewmembers in the airlock that can be transferred is being studied by NASA. The maximum quantity under the above conditions was not available at report preparation. However, the information should be available for payload design use by late 1976.